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ABSTRACT

This workbook provides descriptions of research projects for high school and middle school science teachers and students. The projects can be used as demonstrations in the laboratory or classroom to help teachers illustrate the practical application of basic science principles. They can also be used by students, under the guidance of the teachers, as starting points for independent projects to present at science fairs. The projects, which vary in level of difficulty to accommodate both the gifted and average students, are presented under these headings: animal nutrition; animal physiology and biochemistry; animal reproduction; aquatic sciences and fisheries; electricity; food science and food products; forest products; human nutrition; insects; plant breeding; plant diseases; plant nutrition; plant physiology and biochemistry; recycling; seed physiology; soil biology; soil chemistry and physics; soil classification and genesis; soil cultivation; and solar energy. Descriptions include background information, problem, materials, methods (procedures), references, and the name of the person who submitted the project. Also included are tips for obtaining reference materials, how to write for information (including samples of unacceptable/acceptable letters), guidelines for animal use, and a discussion on how to conduct a research project. (JN)

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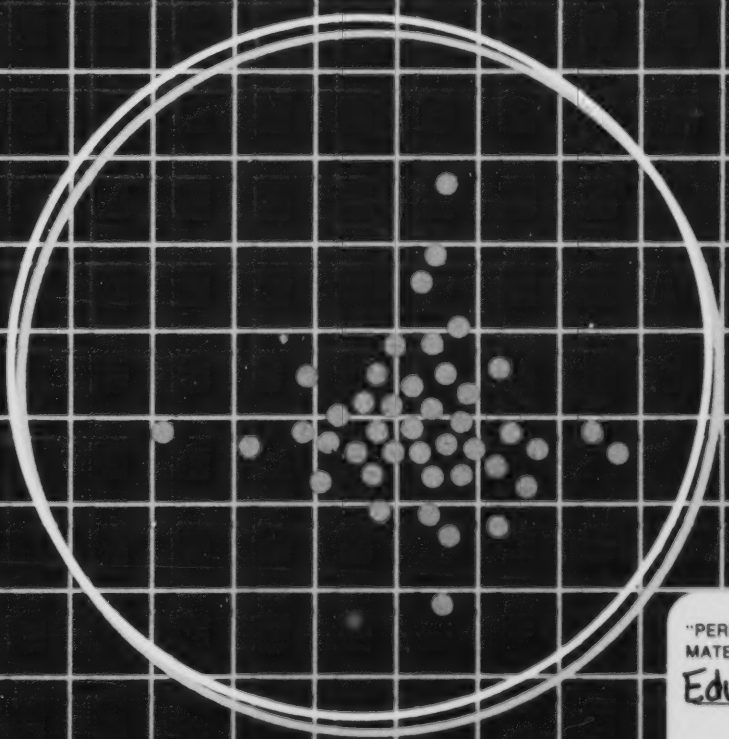
The Science Workbook

Student Research Projects in Food — Agriculture — Natural Resources



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THE SCIENCE WORKBOOK

OF STUDENT RESEARCH PROJECTS IN

FOOD - AGRICULTURE - NATURAL RESOURCES

1985 Edition

Edited by

Edward E. Darrow

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FOREWORD

This workbook is intended to be a handbook for high school and middle school science teachers and students. It is anticipated that in many instances teachers will find it helpful to make the workbook, or copies of specific pages, available to students. Therefore, most authors have written their projects and articles with student readers as their target audience.

The projects in this book can be used as demonstrations in the laboratory or classroom to help the teacher illustrate the practical application of basic science principles. Or, under the guidance of the teacher, this workbook can serve as a resource from which students can select topics for independent investigation to present at science fairs. The projects vary in level of difficulty to accommodate both the gifted and average student.

This workbook was created for several reasons:

1. to promote the fact that the food, agricultural and natural resources sciences are, in essence, the practical application of the biological and physical sciences.

2. to encourage the active involvement of students in scientific inquiry to develop their problem solving skills. Recent research documents the effectiveness of hands-on, inquiry oriented science courses in enhancing higher-level intellectual skills such as critical thinking, problem solving, creativity, and process skills as well as a better understanding of scientific concepts.

3. to strengthen the library research skills of students.

4. to stimulate the interest of students in research projects in the food, agricultural and natural resources sciences and to encourage their future continuing involvement.

5. to serve as a model for other Colleges of Agriculture as one way to create stronger linkages between the University and science teachers in public and non-public secondary schools.

The author's name and address is listed at the end of each project. Teachers and students should feel free to contact these faculty with questions about their particular projects. A suggested letter for students to follow in writing for information is printed at the end of this workbook.

ACKNOWLEDGEMENTS

I would like to thank the many people who assisted and encouraged us in this effort.

Our sincere appreciation is extended to the faculty of the College of Agriculture who authored these 53 research project outlines because of their continuing interest in stimulating excellence in the classroom and laboratory.

Thank you to The Ohio Academy of Science, and especially Mr. Lynn Elfner, Executive Officer of the Academy, who generously gave us ideas to be included in this book and reviewed the projects.

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DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D. C. 20250

Subject: Science Project Workbook

To: High School Science Teachers

The extraordinary success of the U.S. food and agricultural industry is well known, and it is basic to the international security of this Nation. The growth and productivity of this industry have largely resulted from a significant increase in the application of science and technology. To assure the future success and well-being of this strategic asset, however, the food, fiber, and forest industries need to attract scientifically and technologically literate young people.

American agriculture has a tremendous capacity to produce in a highly efficient manner. It represents an unquestionable national asset essential to providing high-quality and reasonably priced food. The current challenge is to develop new technologies to assure that high quality, reasonably priced food, clothing, and shelter are available in the future for American consumers and world markets.

The food and agricultural sciences are disciplines in which the biological and physical sciences are applied to the production and processing of food and fiber raw materials and products. These sciences include animal/human/plant nutrition, animal/plant physiology, biochemistry, botany, cellular and molecular biology, genetics, and microbiology, as well as chemistry, mathematics, computer science, statistics, and physics. These sciences are applied daily by food and agricultural scientists and managers in business and industry, education, and government.

In an era when scientific and technological information can quickly become obsolete, it is imperative that students develop enduring critical thinking skills and problem-solving competencies. To do so requires substantial learning opportunities to practice the scientific method. We applaud the publication of this workbook as an effort to encourage scientific literacy and the conduct of science by America's students.

John R Block

CONDUCTING A RESEARCH PROJECT: FOR THE YOUNG SCIENTIST

BACKGROUND

The purpose of this article is to assist the beginning investigator who is planning a science project for a class or who wishes to participate in the local science fair. Planning and conducting a science project can be a very exciting and rewarding way to actively participate in science. It may also help you to discover some career opportunities for your future.

The scientific investigation is a way to learn by direct experience. The student research projects outlined in this workbook are intended to be a source of ideas for problem solving, i.e. identifying problems, making decisions and evaluating outcomes. They provide an opportunity to extend the learning experience beyond the printed word of the textbook, which often contains the organized product of science, into the process of science.

This workbook is a source of ideas for one specific type of science project -- the experiment. Other types of science projects such as a demonstration of a scientific principle, a rigorous description of a phenomena in science, or the classification of observations are all ways to learn more about science. However, they should not be confused with experimentation which goes beyond the attempt to demonstrate, describe or classify.

The purpose of experimentation is to solve problems in an unbiased way. Because man is often biased, scientific methods have been devised to insure that he is objective in his decision making about a problem. It would seem to be easy for a young scientist to do research, but the untrained mind seldom has learned the techniques of guarding against unbiased decisions. (9, p.12)

Due to the uniqueness of each investigator, situation and problem to be solved, there is no single scientific method, or process of science, or method of inquiry to be used for all experiments. The steps outlined below are provided as a guide for you to follow using the traditional methods of an experimental scientist. You will also find the 20 minute videocassette "Planning Your Science Project" to be very helpful (see reference 10).

IDENTIFY PROBLEM

The authors of the projects in this workbook have identified problems in the food, agricultural and natural resource sciences which can be investigated. There are two important considerations for you to consider in selecting a problem to investigate. First, it should be of interest to you. This will not only make learning more enjoyable but can also lead to an awareness of careers.

The problem should also be narrow enough to be realistic in terms of the definition of the problem to be investigated and the time it will take you to complete the experiment. A topic such as animal nutrition is too general. However, the nutritional value of mealworms for certain zoo animals might be a very realistic study.

After reading through some projects in this workbook, you may find it helpful to modify a project to meet your interests, timetable and materials needed. Do not be concerned about the title of the project at this time. That will become more apparent when you do the library research.

FORMULATE HYPOTHESIS

After you have identified a problem and written a description of the problem, then you are ready to formulate a tentative hypothesis by reasoning and making assumptions. The formulation of a hypothesis is one of the distinctive characteristics of experimentation as opposed to a demonstration. The hypothesis is a statement to be proved or disproved.

To develop the hypothesis, start by asking questions about the problem. For example:

Will strenuous exercise adversely affect reproductive cycles of non-human animals?

Which food preservative is best for preventing mold growth in bread?

Does soil type affect the rate at which petroleum products decompose in soil?

Will popcorn seeds soaked before planting grow faster than dry seeds?

Then, rephrase the question into a hypothesis. It should predict a possible result and should be phrased as a testable statement. Often the hypothesis is a scientific guess as to what the investigator believes the outcome will be. For example: Popcorn seeds soaked in water prior to planting will grow into taller plants at 21 days than dry seeds.

After a tentative hypothesis has been formulated, you should next perform a search of the literature on this problem. Reading about the results of other investigators may give you an idea for modifying your hypothesis. A precisely stated hypothesis will also help to suggest how to design the investigation.

LIBRARY RESEARCH

Your experiment will be incomplete without a thorough literature review. The article titled "Tips for Obtaining Reference Materials" contained in this workbook provides a detailed description of the process for reviewing the literature. The primary purpose of the library research phase is to gain further insight into your problem by reviewing the results of previous investigations on this topic or related topics. The references at the end of an article can lead you to more information. You can also obtain ideas about the methodology or investigation design which has or has not worked for other investigators, the statistical techniques they used to analyze their data and the ways in which data is presented in tables and graphs.

Make reference cards on each book, article or other source you consult. Also take notes, either direct quotes or as a paraphrase, as you read the literature. You will need this information to

write the background for your report.

DESIGN INVESTIGATION

This step in the experimentation process is often called "the methodology". It should be the design or method describing exactly how you plan to test the hypothesis. The design should be written in enough detail that another investigator can read it and be able to duplicate your experiment. There are several types of experiment designs ranging from the simple controlled experiment to the survey technique used to sample or collect data from a group. You will need to select a design for your investigation that best tests your hypothesis.

The design of your experiment should anticipate the data you will need to collect and the statistical analysis you will use to accept or reject your hypothesis. This will help determine the procedure (how collected, when, etc), the type of measurement (height, weight, units to be used, etc.) and the format of the tables (column headings) you will use to collect the data.

The method of testing the hypothesis is important in an experiment because normally there are numerous variables involved. Therefore, the simple controlled experiment is frequently used in biological research to attempt to assure that only the variable being tested is affecting the results. The investigator attempts to eliminate all other variables by running in parallel two or more experiments identical in every respect except one so that whatever differences are observed will be due only to the single, known variable. The intent is to change one variable at a time (called the independent variable) in order to observe any change or outcome (called dependent variable).

In a simple controlled experiment, the design should include a "control group" and an "experimental group". For example, assume that you wish to determine the effect of nitrogen fertilizer (an independent variable) on the growth of young bean plants. If you plant some beans, fertilize each plant with 1 gram of ammonium nitrate fertilizer (N) and the beans grow well, you might conclude that the N helped them grow. But without a "control" of 0 grams of N, you have no way of knowing whether the beans might have grown the same amount without the nitrogen. You need a group of bean plants as a control for the purpose of comparison.

Now suppose you wish to determine the effect of different amounts of N on the growth of young bean plants. You plant 120 beans, fertilize 30 plants with 1 gram of N, 30 plants with 2 grams of N and 30 plants with 4 grams of N. These are the experimental groups. Thirty plants should also receive 0 grams of N. This is the control group.

The design of your experiment should try to anticipate sources of experimental error which could bias your data. In the bean experiment above, variables such as the amount of water given each plant, differences in soil in individual pots, and the amount of light and temperature could influence the growth. In a controlled experiment, all of these variables must be as identical as humanly possible for both the experimental and control groups. For example,

if you planted some small, cracked bean seeds for the control group and all the other seeds planted were large and undamaged, error has probably been introduced into the experiment. Error could also be introduced if one experimental group of plants was located nearer a window than the others. Labeling and randomly assigning a location to each pot in which a bean seed has been planted would reduce this source of error. This is called randomization and this technique should be used whenever possible to remove systemic error.

The controlled experiment should also be designed to have enough subjects in both the control group and experimental groups that you can have confidence in your results. You will have more confidence in your conclusions if you have 30 bean plants in each group rather than one. You need to make your groups large enough to rule out the possibility of normal, individual differences. If you need help in determining the size of your groups, seek the advice of a professional trained in statistical analysis.

Replication, or repeating the experiment, also serves to diminish the error in test results. If time permits, it would be good experimental design to repeat the experiment two or three times.

If your experiment involves the use of laboratory animals, there is both a scientific and ethical responsibility for the humane care and general welfare of these animals. The article titled "Care and Use of Laboratory Animals" contained in this workbook provides references for guidelines and recommendations. Do not let the guidelines discourage you from investigations involving experimental animals. Nothing in the guidelines is intended to limit an investigator's freedom -- indeed, obligation -- to plan and conduct animal experiments in accord with scientific and humane principles. (5, p.2)

WRITE PROPOSAL

Up to now, you have been planning your experiment. You have identified a problem, formulated a hypothesis, read the literature and decided upon the design of your investigation. Before you begin your experiment, you should write out a statement about each of these areas in the form of a mini-proposal (2-3 pages). Share it with your teacher or another professional and ask for suggestions to improve your experiment. If you plan to contact faculty at a university or researchers in industry for assistance, send them a copy of your mini-proposal. It will make it easier for these busy people to respond to your questions.

COLLECT DATA

Any measurement in collecting data is subject to sources of error. The object in this phase of the investigation is to anticipate where those sources might be in the experiment and to attempt to minimize the error. The data should be entered into tables which you devised in the investigation design. You should record the data in a notebook and also record other non-statistical observations about your control and experimental groups. The latter observations may later help you explain a particular result you

did not expect.

After the data is collected, you are ready to analyze it in an exact and impartial way. Estimators of central tendancy (the mean or average, median and mode) are generally the most useful all-around statistics to describe biological variables. However, by itself, the mean of a control or experimental group leaves much to be desired because it is strongly influenced by a few extreme values. A measure of the degree of dispersion about the mean of the group is needed. One such measure you may wish to compute is the standard deviation. (14, p.20)

There are other statistical tests which may apply to your data to help you interpret whether the mean of the data for an experimental group is significantly different from the mean of the data for the control group. It is suggested that you consult some of the basic statistics books in the library or a professional trained in statistics if you need help with the standard deviation or a test of significant difference between the means.

DRAW CONCLUSIONS

This step in the investigation is where you decide to accept or reject your hypothesis. The analysis of your data will either support your hypothesis or it will not. This must be stated in your conclusion. Be cautious that your conclusion is not a new hypothesis (12 p.34).

In an experiment, the investigator attempts to draw conclusions about the general population based upon data taken from a sample. You conclude or infer from the specific to the general. Let's return to the bean experiment mentioned earlier. You collected data on a sample of 30 beans in one experimental group to which N (a variable) was applied. You can only infer that all bean plants (the total population) will have the same response. The probability of this would not have been very high if the sample size was only ten bean plants. But your confidence in concluding that this result will happen to the total population is much higher with a sample of 30 bean plants.

Hence, it is important for you to draw conclusions about the relationship among the variables but to do so within the limits of the data. Are your conclusions valid? Is it possible the results you obtained could have been caused by some other variable?

WRITE REPORT

Now you are ready to switch from being an investigator to becoming a scientific author. Your research project should be presented in a concise, written report. The following is a conventional form for a formal (scientific) report.

Supplements that precede your report:

- -cover
- -title page
- -abstract (a mini-report)
- -table of contents
- -table of figures (as needed)

The report:
- -introduction (including background, statement of problem and hypothesis)
- -experimental design
- -analysis of results (including tables and graphs)
- -conclusions
- -references

Supplements that follow your report:
- -glossary (as needed)
- -appendixes (as needed)

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AUTUMN LEAVES OR GRASS CLIPPINGS AS A SOURCE OF FOOD FOR RUMINANTS

BACKGROUND

Ruminant animals such as sheep and cattle have the capability of digesting fibrous foods because they have a four compartment stomach, of which the first two (the rumen and reticulum) operate as a fermentation vat. Anaerobic bacteria and protozoa growing in the rumen and reticulum of ruminants have cellulase enzymes to digest fiber in the stems and leaves of plants. Since mammals do not have the capacity to produce cellulase enzymes, a unique symbiotic relationship exists in the ruminant. The animal provides a favorable environment for the microbes to grow and the microbes, in turn, digest fibrous foods providing energy, protein, and vitamins to the animal. Tremendous quantitites of autumn leaves and grass clippings are produced annually in the U.S. These fibrous products represent a potential source of food which rumninants could use for the production of wool, meat or milk. There has been very little research conducted to determine how well rumen microbes digest these residues and if they could be used as feedstuffs for ruminants.

PROBLEM

Determine the digestibility of grass clippings and/or autumn leaves by rumen microbes. Can the digestibility be improved by physical treatment such as grinding or chemical treatment by mixing with 1 to 5% ammonium hydroxide? Grinding increases surface area for microbial attack and ammonium hydroxide alters the chemical structure of fiber and increases its availability to microbial cellulases.

8

METHOD

Microbial digestibility can be determined by in vitro fermentation of a known quantity of foodstuff and measuring either sample weight loss or volatile fatty acid production during fermentation.

1. Weigh exactly .5 gm of sample into 50 ml capacity test tubes. A minimum of 3 tubes should be done for each forage treatment. Determine dry matter content of all residues tested by weighing duplicate 10 gm samples for each residue into aluminum pans, drying at 215°F overnight and reweighing residue.

$$\% \text{ dry matter} = \frac{\text{sample weight after drying}}{\text{sample weight before drying}} \times 100$$

2. Strain fresh rumen fluid from local slaughter plant through 4 layers of cheesecloth into a 1 quart thermos. Just prior to inoculating the test tubes slowly mix an equal volume of warm (100°F) water (containing 10 gm of sodium bicarbonate /liter) with the rumen fluid. Rumen microbes cannot tolerate cold or oxygen. Care must be taken to keep the inoculum warm and to not stir it vigorously which would introduce oxygen into the fluid.

3. Slowly add 30 ml of inoculum to each test tube and place stopper loosely in tubes so that fermentation gases can escape. Also, add inoculum to 3 tubes without sample to use as a blank.

4. Place tubes in 100°F incubator. Swirl tubes initially and at 6-8 hr intervals to aid mixing of sample with inoculum. Avoid washing particles onto wall of test tube above fluid level. Gas bubbles in the tube will indicate a successful fermentation.

5. Measure pH of tubes initially and at 12 hr intervals as an estimate of volatile fatty acid production.

6. After 48 hrs. of incubation, kill the rumen microbes by adding 2 ml of a 50% solution of water and concentrated hydrochloric acid. Filter samples through previously weighed filter paper, dry filtered samples at 215°F overnight, and weigh.

7. In vitro dry matter digestion =

$$\left(1 - \frac{\text{weight of sample after drying - filter paper weight - blank)}}{\text{weight of original sample x \% dry matter from step 1}}\right) \times 100$$

8. A fermentation pH curve can be drawn for the various treatments. Also in vitro dry matter digestion can be determined over time rather than at just 48 hrs. by making measurements at other times.

9. In general, alkaline agents increase digestibility of fiber. Any number of these could be tested.

NOTE: Fermentation volatile fatty acids have a unique odor; therefore, it may be best to conduct the incubations where they will not offend anyone or where there is good ventilation.

MATERIALS

1. Fresh rumen contents (from local slaughter plant)
2. Test tubes
3. Balance to weigh .5 gm samples
4. pH meter or pH paper to measure volatile fatty acid production
5. Filter paper and filter funnel to filter samples after fermentation
6. Oven set at 100°F for incubation of samples during fermentation and set at 215°F to dry filtered samples after fermentation.

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DIETS FOR ZOO ANIMALS - THE NUTRITIONAL VALUE OF DIFFERENT TYPES OF WORMS

BACKGROUND

Feeding zoo animals is a costly process. Because many species are rare and perhaps even endangered, one cannot afford to make errors in providing feed for these animals. Often the "natural" foods for a particular animal are unavailable. In such cases, substitutions must be made which provide the same amount of energy and similar nutrient distributions, i.e., protein, carbohydrate, fat, vitamins, and minerals. Food which is entirely unlike the animal's natural diet in looks may be entirely satisfactory from a nutritional standpoint.

Clearly, the zoo animals themselves cannot serve as experimental subjects to determine the nutritional adequacy of a particular diet or dietary component. Instead diets must be formulated based upon knowledge of the animals' natural diets, nutritional requirements of similar species and sources of particular nutrients. Testing of various diets might be accomplished by using domestic or laboratory animals with a physiology similar to the exotic animal; for example, an exotic ruminant might be compared to a sheep, an exotic sea bird to a duck, a land bird to a chicken, a wild boar to a domestic pig, etc. Such experiments, however, are very time-consuming and costly.

In order to make logical and appropriate substitutions, the composition of various foods must be well documented. Vitamins and minerals can usually be added in appropriate amounts using supplements. If an animal's diet contained (by weight) 30% protein, 20% fat, 30% carbohydrate and 20% of other components (fiber, minerals and vitamins), the health and reproductive performance of the animal might be severely impaired if only 10% protein was provided. Thus, it is necessary to know the composition of any proposed diet.

One item frequently used in the diets for birds and small animals is mealworms. Mealworms are not actually worms at all but rather are the larvae stage of Tenebrio. They are relatively expensive. Could some type of worm such as the earthworm which is easily available and relatively inexpensive, be substituted for mealworms in animal diets? Any other worms which might be substituted should not be parasitic in any of their life stages to the animal to which they would be fed.

PROBLEM

Determine the relative nutritional values of mealworms and earthworms.

MATERIALS AND METHODS

In order to compare the nutritional value of mealworms and earthworms, it is necessary to determine the gross composition of each of these species, i.e., the quantity of moisture, fat, protein, carbohydrate and minerals for a given weight of each type of worm. This may be accomplished by a technique called proximate analysis invented over 100 years ago by two German scientists. To perform this technique, divide samples of each type of worm into nine groups (5gms. each is easy to work with). (Analyses ought to be performed in triplicate.) Weigh each sample carefully (to the nearest .1gm) and record the weights. Dry all of the samples at 100°C to a constant weight and again record the weights. The loss in weight represents the moisture content.

Next select three samples from each group and perform a Kjeldahl digestion to determine crude protein. You may need to consult your chemistry teacher or a basic chemistry textbook for the details on this technique. Select three more weighed samples from each group and put them in crucibles in a high-temperature oven or kiln (500°C) for at least 12 hrs. until only a white (carbon-free) powder ash, remains. Weigh the ash. This represents, to a first approximation, the mineral content of the dried sample.

Select three more samples from each group and extract each sample with petroleum ether (consult your chemistry teacher about performing this extraction safely). After repeated extractions, evaporate off the solvent and weigh the residue which represents the crude fat portion of the sample. The carbohydrate portion can be obtained by "difference", i.e., the weight that is left after the protein, fat and ash are summed. In reality the carbohydrate portion includes other components as well and may not be 100% digestible in a particular animal. To determine total calories, two methods may be used. The most accurate is bomb calorimetry, but the necessary equipment may not be available. An alternative is an estimation of calories by calculation. Since you have determined the composition of the worm samples, it is possible to determine the equivalence of calories/gm by using the 9 calorie/gm for fat and 4 calories/gm each for carbohydrates and proteins. There are no calories in the ash fraction.

Mealworms are available from pet stores and earthworms can be obtained during warm weather from any yard or garden. Other types of worms are available from biological supply houses. It should be possible to perform this experiment in any school chemistry lab (the ashing oven or kiln may be borrowed from an art department).

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12

INFLUENCE OF FORAGE PLANTS ON FERMENTATION GAS PRODUCTION IN THE RUMINANT

BACKGROUND

During the digestion process in ruminant animals, bacteria and protozoa located in the rumen ferment soluble and structural carbohydrates and produce nutrients that can be utilized by the host for productive purposes. During this metabolic process carbon dioxide, methane and hydrogen gases are produced. (A sheep may normally rid itself of 6 liters of ruminal gas per hour). These gases are normal rumen microbial end products but can cause bloat (distention of the rumen), which can be fatal to the animal if not removed by eructation. Bloat is associated with the eating of legumes and to a lesser extent with some grasses, particularly at early leafy stages of growth. Earlier research efforts related to bloat control and treatment did concern some aspects of the peculiarities of plant products involved. However, not much work has been done to measure gas production derived from specific forage plants, plant parts or plant fractions. There is a renewed interest in utilization of immature legumes and grasses by grazing ruminants. Thus, a better understanding of gas production potential of forage substrates is warranted.

PROBLEM

Quantitatively, what is the rumen microbial gas production from forage plants at different vegetative stages?

MATERIALS AND METHODS

Common laboratory glassware can be adapted for fermentation and gas collection vessels. Collection of forage samples and/or other substrate materials and preparation for use in the fermentation system should be carried out in a well planned and organized manner. Viable rumen microorganisms are essential. There are several possibilities for obtaining a good rumen inoculum. Any interested student is encouraged to explore the feasibility of conducting such a project independently and then verify a proposed approach with the author.

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4. Additional references and source materials are available from the project author.

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NUTRITION STUDIES USING CHICKS

BACKGROUND

Approximately 40 different nutrients must be supplied by the feed if a chick is to grow well and remain healthy. An example of a diet which will meet nutritional needs for a chick from 0 to 28 days is given in Table 1. Ingredients which supply energy or calories take up more than half of a typical diet for a chick. Amino acids, which the chick receives by digesting protein, vary from as low as .2% of the diet to as high as 3% of the diet. About 20 different amino acids are in protein. The amounts of macrominerals, such as calcium, phosphorus and sodium, range from .15% to about 1% of the diet. Other nutrients, such as vitamins and trace minerals, need to be present in very small amounts. Their amounts are usually measured as parts per million (ppm) or milligrams per kilogram of diet (mg/kg). A deficiency of any one of these nutrients will affect the growth and health of the chick.

Table 1. Ingredients in a chick starter diet.

		Nutrient supplied	
Ingredient	% by Wt.	Primary	Secondary
Corn	53.30	Energy	Protein
Soybean meal	38.00	Protein	Energy
Fat or oil	5.00	Energy	
Dicalcium phosphate	1.70	Phosphorus	Calcium
Limestone	1.20	Calcium	
Salt	.40	Sodium	
Vitamin mix*	.25	Vitamins	
Trace mineral mix**	.05	Trace minerals	
Methionine	.10	Amino acid	

* A chick needs vitamins A,D,E,K,B_6,B_{12}, thiamin, riboflavin, niacin, pantothenic acid, folic acid and biotin. Choline is also usually added.

** A chick needs copper, iron, manganese, selenium and zinc.

DESIGN

When a nutritional study is conducted, at least two groups of chicks should be used. One group should be fed the "control" diet, - - the diet which is nutritionally adequate. This group will be the standard for comparison. A second group should be fed a diet which is nutritionally modified. Because of variation among chicks, at least 5 chicks should be in each group to provide an accurate answer. More chicks per group are needed if treatment differences are fairly small.

PROJECT IDEAS

1. For the easiest type of project, a feed ingredient can be omitted from the experimental diet and the effects on the chicks can be observed. You can use subjective results such as the effect on the activity and behavior of the chicks. You can use objective measures such as the daily or weekly weight gain of the chicks and the amount of feed eaten each day or week.

2. A more difficult variation might be to find out which vitamins need to be included in the vitamin mix. Corn and soybean meal contain at least a little of all the vitamins. In the case of some vitamins, corn and soybean meal provide enough to meet a chick's requirement. Therefore, none of that vitamin needs to be included in the vitamin mix. In other cases corn and soybean meal do not provide enough of the vitamin, so that vitamin must be included in the vitamin mix in order to prevent a deficiency.

In order to determine if a vitamin needs to be included in the vitamin mix, the control diet should contain all vitamins. The experimental diet should omit the vitamin in question. Subjective and objective results will indicate if the vitamin needs to be added. In some cases, chicks will develop a physical problem which indicates a specific vitamin deficiency.

3. If a vitamin should be included in the vitamin mix, it is possible to find out how much should be added. Different groups of chicks should be fed graded levels of the vitamin. At the point where higher levels of the vitamin no longer improve health or growth, the requirement has been reached.

4. If you want to find out the total amount of vitamin needed - i.e. vitamin in the mix plus in the corn and soybean meal - then an assay for that nutrient must be done. A method of assay is available for each nutrient and most assay procedures use chemical or microbiological tests. Tests are also available to show how nutrient levels in the diet affect nutrient levels in tissues or blood.

5. Another possibility is to use the chick for a biological assay. If the diet is deficient in a nutrient, then that diet can be used to compare amounts of that nutrient supplied by different foods or feeds. For example, assume that a diet has been found to be deficient in riboflavin. If you substitute 5% brewer's yeast for 5% soybean meal, the chicks fed the diet with 5% brewer's yeast will probably grow faster and be healthier. You could conclude that brewer's yeast is a better source of riboflavin than soybean meal.. By designing the proper experiment you could also determine how much better brewer's yeast is than soybean meal.

REFERENCES

1. Association of Official Analytical Chemists Handbook. This book contains the official method of analysis for most of the nutrients. Published by: AOAC, 11 North 19th St., Suite 210, Arlington, VA 22209

2. Nutrient Requirements of Poultry, 1984 (8th edition). Gives the nutrient content of feed ingredients, lists nutrient requirements for poultry, describes effect of each nutrient deficiency and supplies other references. Costs about $12 and can be ordered from: Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Ave., NW Washington, DC 20418

3. For additional help contact the author at address below.

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RUMINATING ON RUMINANTS

BACKGROUND

Much criticism is directed toward food animals on the grounds that they are inefficient processors of energy. It is repeatedly pointed-out that several pounds of grain are required to produce one pound of edible animal product. In a world in which starvation and undernourishment are prevalent, the disadvantages of consuming animal rather than vegetable products seem apparent.

In the face of this continuing anti-animal criticism, it is important to understand and to emphasize the important role which ruminants play and the appropriate place which they command in the food chain. Ruminants possess the important property of being able to convert grasses and other fibrous plants (roughages), which are virtually inedible, to highly nutritious meat and dairy products. In the process, proteins are produced which are much more complete or well-balanced in terms of amino acid composition than are typical vegetable proteins.

The roughage conversion process is important because there are times and places where the growth of roughages is either necessary or highly desirable. On range and rough land only roughage crops can be grown. On rolling land, grass strips help control erosion. On all row-crop land periodic planting of a roughage crop helps improve soil tilth and control disease. The ruminant animal provides a means of harvesting this crop.

The ruminant is able to convert roughage to meat or milk because it possesses a specialized series of stomachs capable of digesting the fibrous materials that simple-stomached animals like man cannot.

The heart of the process resides in the rumen, the largest of the four stomach chambers. Here a population of resident bacteria break down the cellulose in the plant cell walls, converting it to simpler sugars and freeing the contents of the cell for digestion. The products, including many of the bacteria, are then processed in the other stomachs.

PROBLEM

Demonstrate the 4-compartment ruminant stomach, show some of the species of bacteria which populate it, and explain some of the functions they perform. What are the differences in ruminant digestiblity of fibrous materials in vitro?

MATERIALS AND METHODS

The 4-compartment ruminant stomach system could be shown in diagram, or, with a little more work, a 3 dimensional model could be made. A microscope could be set up showing some species of rumen bacteria and protozoa. These could be obtained from fistulated animals at the Ohio Agricultural Research and Development Center, from rumens in a slaughter house, or from live animals by stomach tube, with the cooperation of a local veterinarian. Digestion demonstrations could be set up in small flasks containing rumen fluid. Differential digestion of fibrous materials could be examined by placing samples of cotton, cardboard, leafy alfalfa, etc. in separate flasks. The flasks should be at 37°C. To achieve anaerobic digestion, they should have an air lock such as can be obtained at wine making stores.

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AMPHIBIANS AS A MODEL TO STUDY THYROID STIMULATING AND INHIBITING COMPOUNDS

BACKGROUND

The thyroid is a remarkable organ with the ability to concentrate iodine and produce thyroxin and other iodionated compounds which regulate metabolic rate. Dysfunction of this organ or interference with the proper synthesis of the thyroid hormones can have marked effects on the well-being of the animal. Very simplistically, we might say that excessive production of thyroxin by the thyroid may create hyperactivity, while suboptimal output can produce sluggishness. In reality, an abnormally functioning thyroid may have many serious implications.

In order for the thyroid to function properly the animal must receive adequate quantities of iodine to produce thyroxin. In cases of insufficient thyroxin production, thyroid tissue from another animal, synthetic thyroxin, or iodionated casein can be used for replacement therapy. However, a number of compounds have been identified which can interfere with thyriod activity. Among these are chemicals such as thiourea, thiouracil, and propylthiouracyl. Other compounds, including sulfa drugs and paraaminobenzoic acid, have similar action. Natural products can also interfere, examples being seeds from cabbage, turnip, rape and kale plants. Recently, it has been suggested that some pesticides and industrial chemicals may interfere with thyroid function.

The thyriod plays a very important role in the metamorphosis of amphibians from the larval (tadpole) to the adult. Studies have shown that this metamorphosis can either be inhibited or stimulated by the addition or withdrawal of iodine from the water or by the addition of thyroid stimulating or suppressive agents. The tadpole metamorphosis response is extremely sensitive. For example, thyroxin at concentrations of less than 1 microgram per liter of water is minimally effective from frog tadpoles.

PROBLEM

Since amphibian larvae are particularly sensitive to thyroid stimulation or inhibition, determine whether selected compounds are thyroactive in the larvae and to what extent. A wide variety of therapeutic drugs, pesticides, natural products and industrial chemicals are available for evaluation.

MATERIALS AND METHODS

To conduct these studies the student will have to obtain a series of aquariums or other suitable containers for rearing groups of tadpoles. Tadpoles can be obtained either from a local pond, stream or scientific supply house. Carolina Biological Supply Co., (2700 York Road, Burlington, North Carolina 27215) is an excellent source for obtaining the animals plus literature on their care. This company also offers literature and chemicals which will help with metabolic or reproductive experiments with amphibians. Some of the thyroid stimulating agents (iodine, thyroid tissue from other animals) or inhibiting agents (cabbage and turnip seeds) can be readily obtained. Some of the drug compounds may need to be prescribed by a physician and obtained at the local pharmacy (stimulatory:

Proloid, thyroxin, Synthroid, Euthyroid: inhibitory: propylthiouracil, thiocyanate). Keep in mind that some of the thyroactive drugs are extremely potent with only small quanitities required. For example, 10 mg of thyroxin can be dissolved in 5 ml of 1% NaOH, then diluted to 1 liter with distilled water. This stock solution is 1:100,000. Only small quantities of stock solution need be added to experimental containers to obtain the desired concentrations.

Several aspects of these studies will be extremely critical for a successful science project.

1. If wild tadpoles are obtained, it is suggested that a pilot study be conducted to assure that the animals are sufficiently mature to undergo metamorphosis. A pilot study may be advisable for purchased tadpoles as well.

2. For studies to be valid it is critical to maintain appropriate controls. This means that a group of untreated animals will have to be maintained as well as appropriate treatment controls if more than one treatment is applied to a test group. For example, if the experimental design calls for addition of a thyroid stimulating and thyroid inhibiting agent simultaneously, then each of those compounds will have to be given singly to given groups of tadpoles.

3. Another important factor is careful determination of the dose of the test article. These animals may be very sensitive. A good experiment may require administration of several concentrations of the test compound(s).

4. Amphibians maintain at below $5^{o}C$ and may not undergo metamorphosis irrespective of treatment. Temperature of the water may need to be controlled.

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EFFECT OF DAYLENGTH ON EGG PRODUCTION IN JAPANESE QUAIL

BACKGROUND

There is a tremendous variation in day length depending upon latitude. In the United States the longest day of the year is approximately 15 hours and the shortest is 9 hours. At the equator the length of day is fairly consistent. The poultry producer must understand the consequences of this variation and deal with it accordingly. In general, the reproductive system of poultry is stimulated by photoperiods of 14 or more hours duration per 24-hour day. It has also been demonstrated that intermittent lighting schedules have been stimulatory. If the length of time from the beginning of the first light period and end of last light period is 14 hours or more, the poultry producer must work out a lighting schedule which supplements the light supplied by nature or house birds in "light-tight" buildings and supply all the light.

PROBLEM

Is there a significant difference in egg production in birds reared under different lighting regimens? The project should include a review and report on what has been done in respect to supplemental lighting, what conclusions have been made, and design the "ideal" lighting program from an economic and a production standpoint. From a physiological standpoint, how does the available light cause stiumlation of ovulation?

MATERIALS AND METHODS

Japanese quail are an ideal bird to use for this type of study because of the rapid rate of growth and early maturation. Rear 25-day old quail under the conditions outlined by Nestor in reference #1 below. At 4 weeks of age, feather sex the birds (males have bronze colored breast feathers while females have speckled feathers on the breast) and individually cage the females in two sets of three cages. In the morning (7 to 8 a.m.) turn on the lights and place a light tight box over one set of 3 cages. Place something under the box so that it is one inch off of the floor for ventilation. After school (approximately 8 hours later) take the box off of the birds covered earlier. Turn out the lights before going to bed at night (9 to 10 p.m.). This is generally comparable to 2 light periods; 8 hour light:16 hour dark (covered birds), and 14 hour light:10 hour dark (uncovered birds). Record daily egg production of all the birds on an individual basis. Japanese quail are available with adequate prior notice from the Department of Poultry Science of the Ohio Agricultural Research and Development Center, Wooster, Ohio.

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A GRAPHICAL METHOD OF COMPARING THE GROWTH CURVES OF POULTRY

BACKGROUND

Since the early 1900's, geneticists, physiologists and nutritionists have been attacking the mysteries of growth, molding yesterday's economically nonefficient livestock into today's meat producers. The ultimate goal of a livestock producer is to maximize the yield of desirable meat products without reducing the animals' feed efficiency. Genetic manipulation within species has resulted in animals which are quite different in dimension and production purpose. A classic example of this has occurred in the poultry industry. Desirable meat producing broilers are expected to reach market weight of about 2.0 kg in seven weeks whereas egg producing Leghorns are expected to approach 1.2 kg at twenty weeks of age.

A current problem facing the poultry industry is the lack of uniformity of flocks of birds prior to processing. Body weights at a predetermined processing age may vary by as much as .5 kg. Therefore, the flock must be maintained, at the producers expense, until a majority of the birds reach market weight. Also closely associated with uniformity are problems with processing equipment due to different carcass sizes. Selection for increased body weight at a certain age is usually based on a point measurement made some time during the animals' growth period. Although this selection scheme does not improve uniformity, it has been and will continue to be successful because of the high heritabilities of growth traits. If, through selection, the growth curve could be modified to fit the most economical growth pattern, uniformity in body weight and conformation at market age would likely improve.

PROBLEM

Is there a significant difference(s) in growth curves within or between species to enable their use as a selection tool?

MATERIALS AND METHODS

The growth curve of any species may be plotted from birth to sexual maturity through alternate day measurements of body weight. Day-old chicks work very well for studying the growth curve because they grow quickly and mature at a relatively young age. They are also easy to find, normally available from local hatcheries. One should maintain only as many birds as space permits. Chicks should

be marked, preferably wingbanded, immediately after receiving them, for identification purposes. Supply feed and water ad libitum throughout the study. Weigh all chicks on day one, then every other day until the birds have stopped making significant body weight gains. A typical kitchen scale will be accurate enough to measure these data. Determine the sex of the birds upon completion of the study.

Graphically plot all of the data as weight over time for each individual bird. Comparisons may then be made between individual birds. Comparisons may also be made between sexes where data are pooled by sex. Between species comparisons of growth curves may be easily made by plotting the growth curves of chicks and Japanese quail chicks. After the growth curves are plotted visually, compare them using the logistic equation. Examine the curves mathematically to see if significant differences actually exist. The logistic equation describes the growth curve in terms of hatch weight, point of inflection (age when rate of growth is maximum) and asymptote (weight at maximum growth).

Logistic equation:

$$W = \frac{1}{1 + be^{kt}}$$

where W = weight of the organism expressed as a decimal fraction of the final weight, (k) is a constant which is proportional to the overall growth rate, and b is a constant such that the point of inflection occurs at t = o when b = 1. This is completely discussed in reference 2, "A Graphical Method of Fitting Equations to Growth Curves".

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5. Japanese quail eggs are available for incubation from the Department of Poultry Science, Ohio Agricultural Research and Development Center, Wooster, OH 44691.

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THE EFFECTS OF MEGAVITAMIN DOSES ON THE DEVELOPMENT AND GROWTH OF THE CHICK EMBRYO

BACKGROUND

It has become popular with some people to take large amounts of vitamins because they believe that these substances may improve their health. It has been recognized for some time that certain vitamins have pharmacological properties at high levels of intake and may become toxic at megadose levels. It is necessary to distinguish the nutritive requirement levels of vitamins that support normal metabolism from higher levels that may exhibit pharmacological or toxic properties. With most vitamins the nutritional levels are well defined but the increased amounts that induce pharmacological response or toxicity are not well understood.

One of the vitamins that disturbs metabolism and is toxic at high levels is Vitamin A, also known as Retinol. In the past, large doses of this vitamin have been used to treat acne type skin diseases in the human with some side effects of vitamin toxicity. The liver serves as a storehouse for vitamin A by taking up dietary excesses for later release to other body tissues when diet intake is low. In rare cases, liver stores of the vitamin are extremely high and such livers are toxic to animals or humans consuming them, a problem first encountered by Artic explorers and their dogs consuming polar bear or seal liver. Signs of acute vitamin A intoxication include: headache, drowsiness or irritability, vomiting, blurring of vision, incoordinaton, weakness and peeling of the skin. Long term effects include: stiffness of the joints, enlarged liver and spleen, bone thickening, anemia and skin drying with pigmentation.

Excesses of vitamin A are also toxic and teratogenic to the developing chick embryo. High levels of this vitamin disturb metabolism and alter the normal structure of the embryo as well as its extra-embryonic membranes. Hence the fertile egg can be used to study the effect of megadoses of vitamin A on embryogenesis.

PROBLEM

Investigate the effect of supplemental vitamin A on early embryonic development and determine the amounts of vitamin A compounds that alter embryonic structure and are detrimental to the health of the chick embryo.

MATERIALS AND METHODS

Fertile chicken eggs are the biological system for this study. They should be no more than one week old and placed in a suitable egg incubator immediately after administration of experimental treatments. Vitamin A in the form of retinol or retinyl acetate dissolved in vegetable oil is suitable for study. The oil should contain between 20,000 to 50,000 International Units of vitamin A activity per milliliter or gram. The oil solution of the vitamin should be stored in a small closed glass tube or bottle in the dark and under refrigeration because it is easily destroyed. The solution and any dilutions of it should be handled aseptically and warmed to body temperature just prior to use. Graded levels of the vitamin oil between 0.01 and 0.1 milliliters are injected

into the yolk of the egg with a small hypodermic syringe equipped with a 1-1/4 inch, 22-24 gauge sharp needle. Eggs to be injected should be cleansed by swabbing the top half of the egg while standing on its small end with 70 percent ethanol and allowing them to dry for a few minutes. A small hole is drilled or punched into the large end of the egg above the air cell. The syringe loaded with an appropriate dose of vitamin A containing oil is inserted into the hole in the egg in such a manner that the needle is vertical and in line with the long axis of the egg. When the needle is fully inserted, the tip should be in the egg yolk. The plunger on the syringe is pushed very gently to deliver the dose of vitamin A. Carefully withdraw the syringe and seal the hole in the shell with a drop of wax or a small piece of plastic or masking tape.

Treat at least 10 eggs with the same dose and use a range of doses to establish the response of the embryo to excess vitamin A. Incubate the eggs for 5 days and examine them along with non-injected or sham injected controls for degree of embryonic development with the aid of a good candling light. Breakout eggs that seem abnormal and record extent of development and abnormalities observed. Continue to incubate and examine surviving embryos for the full incubation period. Design additional experiments on the basis of your first study using other levels of vitamin A or other sources and forms of the vitamin. Studies of this type can be extended to other vitamins that are toxic in megadose amounts.

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EFFECT OF LITTER SIZE ON LACTATIONAL PERFORMANCE

BACKGROUND

Lactational performance of all mammalian species is influenced by several factors. Age, nutrition level being consumed, length of lactation period, and size of nursing young are some of the more important factors. In certain species genetic composition has a strong effect on the lactational performance. In litter bearing animals the number of young that are nursing can act as a stimulus to lactation.

PROBLEM

Investigate the stimulus to lactation caused by the number of nursing young.

MATERIALS AND METHODS

Pregnant laboratory animals (e.g. white rats or mice) could be divided into two or more equal sized groups of mothers. At birth the litter sizes would be adjusted to either a few young or many young (e.g. two and eight pups) per mother. The effect of litter size lactation performance and weight change of the mother, and on growth of the pups could be determined by weighing the litters and mothers daily over a three week period. The change in individual pup weights during the three weeks would demonstrate variation in animal growth rate.

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EFFECTS OF "BODY CHECKS" UPON HATCHABILITY OF CHICKEN EGGS

BACKGROUND

"Body checks" occur as a result of the egg shell being cracked during their formation in the hen's uterus. Although the crack

is sealed before the egg is laid, the "check" can be seen easily, the shell may bulge at the site of the check, and the thickness of the shell within the fussure is reduced. Because hatchery equipment is designed to accommodate eggs of average size and shape, body checked eggs are usually excluded. If such fertile eggs do not lose excess moisture and hatch at an acceptable rate, they might be utilized by small hatcheries or in home hatchery projects.

PROBLEM

What are the effects of "body checks" upon the hatchability of chicken eggs? Measure the effects of body checks upon parameters such as moisture loss during incubation, embryonic mortality, total shell mass, and quality of chicks hatched.

MATERIALS AND METHODS

Normal and body-checked eggs may be obtained from a local chicken hatchery. Inexpensive incubators having capacity of 50 or more eggs may be constructed following procedures in The Avian Embryo (see references). Construction of the incubators can be considered an integral part of this project.

As a preliminary step, several normal and body-checked eggs should be broken and the thickness of the shells compared using a paper gauge or another thickness gauge. Equal numbers of body-checked and normal eggs obtained from the same stock and of similar ages should be numbered and individually weighted. The eggs can then be weighed periodically during incubation to determine moisture loss. Each egg should be candled (gently) at about weekly intervals to identify infertile eggs and those with dead embryoes. Hatching time of eggs in each group, percent hatchability and health of chicks are among the data that might be collected.

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EFFECTS OF EXERCISE ON REPRODUCTION

BACKGROUND

In recent years, women have become more involved in physical fitness and strenuous endurance sports. At the same time, there has been an increase in the incidence of menstrual dysfunction. Long-distance running and other sports can lead to alterations in hormone levels, resulting in amenorrhea and infertility. The reasons for these effects are not completely understood.

PROBLEM

Determine if strenuous exercise can adversely affect reproductive cycles of non-human animals, such as laboratory rats.

MATERIALS AND METHODS

Female laboratory rats or mice could be used in this experiment. Animals would be divided into two groups, one group to receive strenuous daily exercise and the other group to serve as controls. All animals should be housed under similar conditions and fed identical diets. Exercise could be administered using a small treadmill or exercise wheel. Reproductive cycle performance would be evaluated by daily vaginal smears, looking for the presence of epithelial cells, cornified epithelial cells, and white blood cells. This is a simple technique which requires eye droppers, microscope slides and a microscope. The length of the reproductive cycle would be compared between the two groups.

Vaginal Smears:

Changes in vaginal cytology in laboratory rodents correlate very well with changes in secretion of ovarian hormones. Therefore, it is relatively easy to follow the estrous cycle of the mouse and rat by examination of vaginal smears. The types of cell present at each stage of the estrous cycle will be explained.

Place the mouse on a rough surface. Raise the tail and place 1-2 drops of water in the vagina with a medicine dropper. Aspirate the liquid (this step can be repeated 2-3 times) and transfer the liquid to a microscope slide.

To examine the wet smear: place one end of a cover slip at the edge of the liquid and lower the other end slowly to reduce air bubbles.

To stain vaginal smears:

1. air-dry the smear
2. place in absolute methyl alcohol for 5 seconds.
3. dry in air at room temperature
4. place in Giemsa solution (1:20) for 30 minutes
5. rinse in water
6. dry and observe under microscope

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ARTIFICIAL REEFS IN LAKE ERIE

BACKGROUND

The Ohio Sea Grant program has been working with the communities along the shore of Lake Erie to develop and implement plans for the construction of artificial reefs in the Central Basin. Their purpose was to provide spawning and feeding sites for lake fish, attracting more sport species like walleye and white bass to the area and thus building the tourist economy. The Western Basin has long had the greatest abundance of sport fish because of the presence of numerous rock structures on the shallow basin floor.

Freshwater artificial reefs have been constructed throughout the United States in such areas as Muskegon, Michigan. The Hamilton Reef there has about 4000 tons of rock piled 3-6 feet high in water 26-42 feet deep. Early studies show that the reef attracts sport and bait fish species, especially yellow perch. The perch also spawn there.

The reefs in Lake Erie are a project of the Sea Grant Extension Program of The Ohio State University. Construction permits are held by the Ohio Department of Natural Resources Division of Wildlife. The first sections of a reef were put in place in August, 1984, and studies of their colonization by lake plants and animals could serve as a model for what can be expected in other freshwater artificial reefs.

PROBLEMS

A. Background Research

1. Document the research on the Western Basin reefs that encourages the notion that they attract desirable fish species: what types of fish, numbers, seasons, and reef depths are most attractive?

2. Document the research that has been done on construction of artificial reefs at sea and in other lakes to attract fish. What success stories are there, and what disasters would this new effort need to avoid?

3. Using bathymetric charts, diagram the bottom topography of Lake Erie and indicate what factors went into the choice of sites for new reefs. What is the bedrock like? Where are there concentrations of sediments? What pollution sources must be avoided, etc.?

4. Document the history of development of community support for the reef project. What steps were taken, who was responsible, what happens next?

B. Research Ideas for New Reefs

1. Simulate a reef environment with a computer program. Estimate the effects of various factors on reef success using existing data on water quality, fish movement patterns, seasonal changes in lake stratification, etc. Introduce algae blooms, early ice development, new predator fish, new fishing regulations, and determine the effect on the reef ecosystem.

2. Study actual Lake Erie reefs using SCUBA. Measure water characteristics at various distances from the reef, catalog the species observed, and monitor changes monthly as weather permits. Compare new reef conditions with those of the ancient reefs in the Western Basin.

3. Obtain permission to screen off a section of the new reef for controlled monitoring of some fish that you bring into the area. Make sure your fish are acceptable in the ecosystem first by discussing with experts. Design some measurements that you will take weekly to see if your fish are thriving or in need of something that the reef or the incoming water does not provide. Before working with a live population, be sure you know about the needs of the species. You are not trying to change its life style, only see what the reef has to do with its survival and growth.

4. Based on #1, 2 or 3, develop hypotheses about the sequences of changes that the reef will experience as it develops into a habitat. Include both living and nonliving environmental changes. Predict what would have to happen with reefs or other environmental management in the Central Basin for it to become as important a sport fishing area as the Western Basin.

NOTE: The National Marine Education Association gives annual awards in the National Youth World of Water competition for exceptional science projects in aquatic studies. A project based on artificial reefs could produce a winner.

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MAINTENANCE AND GROWTH OF MARINE PLANTS (E.G. CHONDRUS CRISPUS) IN TANK CULTURE

BACKGROUND

Among the red marine algae (RHODOPHYTA) a number of species have attained considerable economic significance because they are sources for products with useful, functional properties in the food, drug and cosmetic industries. For example, the order, Gigartinaceae, includes the genera and species, Chondrus crispus, a seaweed which abounds in the cool coastal waters in the North Atlantic regions (e.g., Maine and New Foundland). A viscous material called carrageenan can be extracted from these plants in high yields. Carrageenan serves as a stablilizing or thickening agent in many food products.

Chemically, the substance is a polysaccharide with a large content of esterified sulfate (30%). The carrageenan industry relies on harvesting the seaweeds from their natural habitat in coastal waters and in some cases, from areas which have been "cultivated" for this purpose.

PROBLEM

Is it possible to maintain Chondrus crispus in salt-water tanks and accelerate growth by adding selected additives to the water?

MATERIALS AND METHODS

See Table 1 for making artificial seawater for culturing the marine plants. Set up a number of salt-water aquaria or tanks in a cool location (e.g., basement) where the temperature can be maintained around 55-60°F. Locate and collect a number of Chondrus crispus plants, (e.g., Rockland, Maine) still adhering to their "hold-fasts" of small rocks or clam shells. These may be shipped in a large, flexible plastic bag and will remain alive for a few days if an air-pocket of sufficient size is trapped in the bag. Record the weight of the entire plant plus "hold-fast", and transfer it to the well-stablilized and aerated tank. From a knowledge of the chemical composition of the seaweed, determine which mineral elements need to be added to maintain or accelerate growth. Growth can be recorded at intervals, photographically or by weighing the entire plant. NOTE: The growth conditions will be subject to important variables, such as water composition, temperature and lighting.

TABLE 1. Additives for making artificial seawater

Additive	Amount
NaCl	400 mM
KCl	10 mM
$MgSo_4$	20 mM
$MgCl_2$	20 mM
$CaCl_2$	10 mM
$NaHCO_3$	2 mM
$NaNO_3$	0.3 mM
EDTA	27 uM
pH	7.5

The effect of the addition of the following additives on the growth of the marine plants can be studied:

Additive	Amount
"One-a-Day" Vitamin tablets	1-2 tablets per liter salt-water
Fertilizer (N_2)	50-200 mM

NOTE: References 1 and 4 deal specifically with compositon of sea-water and nutrient requirement of marine plants.

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EVALUATION OF AC POWER FACTOR

BACKGROUND

Alternating current in an electrical circuit results from a sine-wave alternating voltage from the central power station. With simple resistance loads, such as heaters and incandescent lamps, voltage and current waves are "in phase," meaning that both pass through zero, increase to a maximum, diminish back through zero, and reach a negative maximum together as one complete electrical cycle, Figure 1. As power equals the product of volts and current (measured in amperes), the maximum net power is delivered in a circuit when in phase.

When the load on a circuit contains coils or capacitors, current is shifted out of phase with voltage, leading (ahead of) the voltage if capacitive and lagging if inductive. Since most industrial loads are composed of motors, which are an inductive load, lagging currents result. This lag is measured in degrees, and the cosine of this angle is called the circuit power factor. Power now equals the product of the voltage, current, and power factor. Power factor can be defined as the proportion of circuit current that is doing useful work; the remainder of the current simply flows back and forth in the circuit. A power factor of less than unity means that some of the current is causing resistance losses (I^2R) without generating saleable energy. And all conductors, transformer, switches, and fuses are larger than necessary to provide the power delivered.

Thus, the electric company encourages high power factors by charging industrial consumers a penalty for low power factors.

One cycle of instantaneous volts, lagging current, and power are shown in Figure 2. If power above the 0 axis is assumed to be positive or delivered power, then that below is negative power; during that part of the cycle energy stored in the magnetic fields is being returned to the circuit. For smaller motors, a power factor corrector can be installed to reduce the voltage to a partially-loaded motor to only that required to maintain rated speed, normally about 1,725 rpm with a 4-pole motor on 60 Hz current. This increases the power factor as much as possible, as shown in Figure 3.

PROBLEM

Perform one or more of the following and interpret your results.

1. Determine motor power factor as a function of load on a fractional HP AC motor, with and without a means of reducing applied voltage, as illustrated in Figure 3. You will need:

   1/3 to 1/2 HP AC motor
   0-125 volt AC voltmeter
   0-6 A AC ammeter
   0-500 W AC wattmeter
   0-10 A autotransformer
   Tachometer or strobe light to measure rpm
   Variable motor load (prony brake, positive water pump with valve, or some other apparatus)

   Full motor load can be assumed when motor current equals that stamped on its nameplate.

2. If a motor test stand or prony brake is available, also determine motor efficiency as a function of proportion of full load, as illustrated in Figure 4. Remember that Power = $2\pi NT/k$, in which the value of k depends upon the units of measurement used. For HP, k is 33,000 if N is rpm and torque, T, is lb-ft.

3. If a dual-trace oscilloscope is available, you may wish to place a small resistance in the circuit to generate a voltage proportional to the instantaneous current, placing both that and the terminal voltage on the scope. If both on horizontal axes, phase angle is illustrated directly. If one of the two voltages is placed on the vertical axis, well-known Lissajous figures result. Sketch and interpret the figures which result from changes in load and voltage.

4. Circuit power factor is corrected industrially by connecting an appropriately-sized capacitor in parallel with motor. Based upon methods described in the references, calculate the required capacitance, in ^{0}F, to improve the power factor of your fully-loaded motor to some higher value, such as from 0.60 to 0.85. If an appropriate capacitor can be obtained, demonstrate its effect. Draw to scale a phasor diagram to illustrate how the phase angle between circuit voltage and current vectors are reduced by addition of the capacitive reactance.

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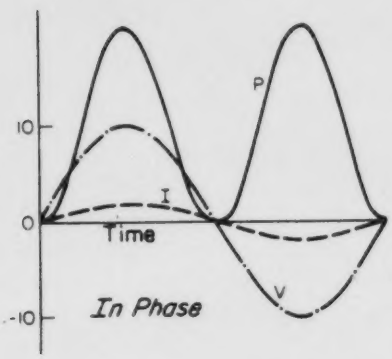

Fig. 1. Power curve (P) when voltage (V) and current (I) are "in phase."

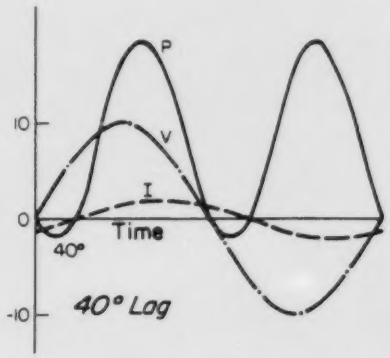

Fig. 2. Power curve when current lags voltage by 40^{0}.

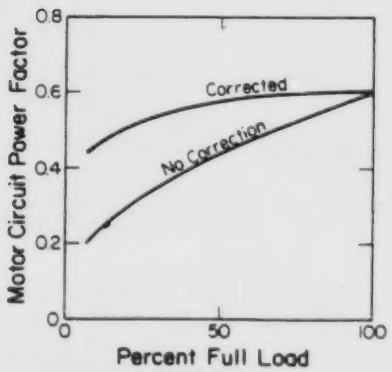

Fig. 3. Effects of voltage adjustment circuit power factor.

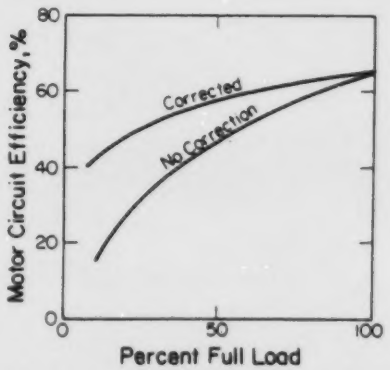

Fig. 4. Effects of voltage adjustment on motor circuit efficiency.

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CONTROL OF MOLDS IN BREADS

BACKGROUND

Bread has been a staple in the diet of man for many centuries. Generally, breads were prepared and baked daily. Certain breads lose desirable texture and taste characteristics upon storage and are also subject to spoilage by certain fungi (molds). Few breads contain natural microbial inhibitors. Today's manufacturing technology has freed us of the task of baking our bread and has yielded a product with a prolonged shelf life. This longer shelf life is partly due to the use of chemicals that inhibit mold growth. Various preservatives (potassium sorbate, sodium benzoate) have been used to inhibit mold spoilage in other food products. Inhibition of yeasts by some preservatives may prevent bread doughs from rising properly.

PROBLEM

Which common food preservatives would be best for preventing mold growth in bread?

MATERIALS

1. A source of bread molds. This may be prepared by opening a fresh loaf of sliced bread, removing the slices and touching them to foreign surfaces, e.g., floor, dirt, grass, etc. replacing the bread and sealing the bag. If the bread is sufficiently moist, molds should begin growing within 4 or 5 days. A blue-greenish mold (Penicillium) or a black mold (Aspergillus) are most likely to grow. This is the mold source for your experiment.

2. Flour, sugar, yeasts, and baking pans for making bread, (Parker House or clover rolls are best and easiest).

3. Small Ziplock freezer bags.

4. The legal concentration of preservatives in breads is .32% of final weight for calcium propionate, .1% for sodium benzoate, and .1% for potassium sorbate. These values correspond to 5 ounces of propionate per 10 lbs. of flour and 1.6 ounces of benzoate or sorbate per 10 lbs. of flour. Other salt forms may be used, e.g., sodium propionate. Chemicals need not be food grade.

PROCEDURE

Overview: A single large lot of flour is to be "inoculated" with mold, then subdivided into smaller portions that will be treated with different preservatives. Dough will be baked into bread and stored in a warm place.

1. Using any recipe for bread or rolls, weigh out and mix all dry ingredients, including yeast. "Inoculate" the dry ingredients

by brushing (with a brush) the mold from the spoiled loaf of bread. Shake a large bag for 5 minutes to thoroughly mix.

2. Weigh out five equal lots of flour sufficient to make 4-6 rolls per lot. To one lot add calcium propionate to achieve a final concentration of .32%; to another add benzoate to .1%; to another add sorbate to .1%; to the others, add nothing. One of these last lots with nothing added will be a control to determine how quickly the bread spoils under normal conditions with no preservatives. The other will use cloves as a preservative. After baking, the whole cloves are to be inserted into the surface of the roll at 3/4"-1" spacings.

3. Add wet ingredients, prepare the dough, let all dough rise under similar conditions, and bake. As soon as the rolls are cool, place them individally into labeled plastic bags that can be sealed (Ziplock or heavy Baggies). It is important that rolls be packaged soon after baking for all products to maintain a constant and high moisture level. As stated above, one lot of rolls is to be treated with whole cloves; another is to serve as a control.

4. Place in a warm place (75^{o}F would be ideal) and observe daily.

Molds are oxygen requiring, therefore, all growth should be on the surface.

NOTE: None of the samples should be tasted. Certain molds are capable of producing carcinogens (cancer producing toxins) under the above conditions.

RESULTS

Record the presence and extent of mold on the various rolls. A trend should be apparent. The mold you observe should be the same type that was used to inoculate the flour. However, other mold types may arise and should be noted.

Record approximate level of mold as:

-	= no mold visible
+	= slight or scant patches
++	= one half of roll covered with mold
++++	= all of roll covered with mold

QUESTIONS

1. Did the bread dough rise equally? Could the different preservatives used affect this? Were all experimental conditions except the levels of preservatives the same?
2. What would be the source of molds other than those that were purposely introduced into the flour?
3. If a small amount of a particular preservative appears to prevent mold growth, then larger amounts would probably be more effective. Why do you think higher levels of preservatives aren't used?

4. Do you think the results would have been the same if the rolls had been permitted to dry out? Why?
5. Natural products, such as cloves, often are very good inhibitors of microbial growth. If this proves to be the case with the clove rolls, why aren't cloves used on all bread products?
6. Why package the rolls individually for observation?

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THE EFFECT OF AN ENZYME PREPARATION AND ITS METHOD OF APPLICATION UPON THE TENDERNESS OF MUSCLE TISSUE

BACKGROUND

Tender meat is appealing to everyone. Tenderness is probably the most critically evaluated of all sensory properties of meat. There are many factors which determine or influence tenderness directly or indirectly such as breed of animal, age at slaughter, diet of animal and activity of the muscles. Regardless of the influence of these factors, tenderness relates to the structure of the muscle tissue. Meat is composed primarily of muscle, plus variable quantities of connective tissues and some epithelial and nervous tissues. The muscle and the connective tissue contribute most to tenderness.

Since today's consumer expects meat which will give the ultimate in eating satisfaction, it is necessary to have proceedures which will enhance tenderness. The use of meat tenderizers containing proteolytic enzymes (papain, bromelin, ficin) have been found to be an effective way to make less tender meat more tender. The effectiveness, however, is very much dependent on proper usage

technique. The use of these preparations has grown to large proportions. Preparations (Adolph's) containing these enzymes are readily available at most supermarkets. Thus, these enzyme preparations may serve as an effective tool to study a method by which one may make less tender meat more tender.

PROBLEM

Evaluate methods which will make less tender cuts of meat more tender.

MATERIALS AND METHODS

A beef "eye of the round" roast or a beef one inch "top round" steak will serve as the biological model for this study. If the "eye of the round" roast is used it should be cut into five steaks, each one inch in thickness. If the "top round" is used it should be cut into five pieces of equal size. Other materials which will be necessary are a 3-5 cc hypodermic syringe equipped with a 1-1 1/2 inch, 22-24 gauge sharp needle in addition to a preparation of Adolph's or other proteolytic enzyme.

The five raw steaks should be treated in the following manner: **Steak I** - no treatment (control); **Steak II** - cover the surface of the steak lightly with the dry enzyme preparation; **Steak III** - cover the surface of the steak lightly with the enzyme preparation and then using a fork, puncture the steak numerous times over the entire surface; **Steak IV** - make a solution using water and a portion of the enzyme preparation. Using the hypodermic syringe, and following the horizontal plane, infuse the enzyme preparation into the steak. Infuse at numerous locations thus assuring equal distribution throughout; **Steak V** - Immerse in the liquid enzyme preparation which you prepared for steak four.

After all steaks have been treated, place them in the refrigerator for six hours before removing and cooking in the oven using a broiling procedure if available. If unavailable, cook in the oven at a temperature of 300^{0}F. Regardless of the method used, cook all steaks for the same length of time. Preference would be to cook 10-15 minutes on one side, turn the steak and cook 10-15 minutes on the other side.

Upon removal of the steaks from the oven, cut them into bite size pieces and serve them to family or classmates asking them to make some judgements as to the degree of tenderness. A scale of one to eight may be used for the scoring with one being extremely tender and eight being extremely tough. Other adjectives such as very, moderately, and slightly may also be used to describe the samples.

Other variations of the project may be to hold the steaks for different time periods prior to cooking as well as holding at different temperatures prior to cooking. In addition, various quantities and concentrations of the enzyme preparation may be used.

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THE EXTRACTION OF NUTRITIONAL PROTEINS FROM UNDER-UTILIZED RESOURCES

BACKGROUND

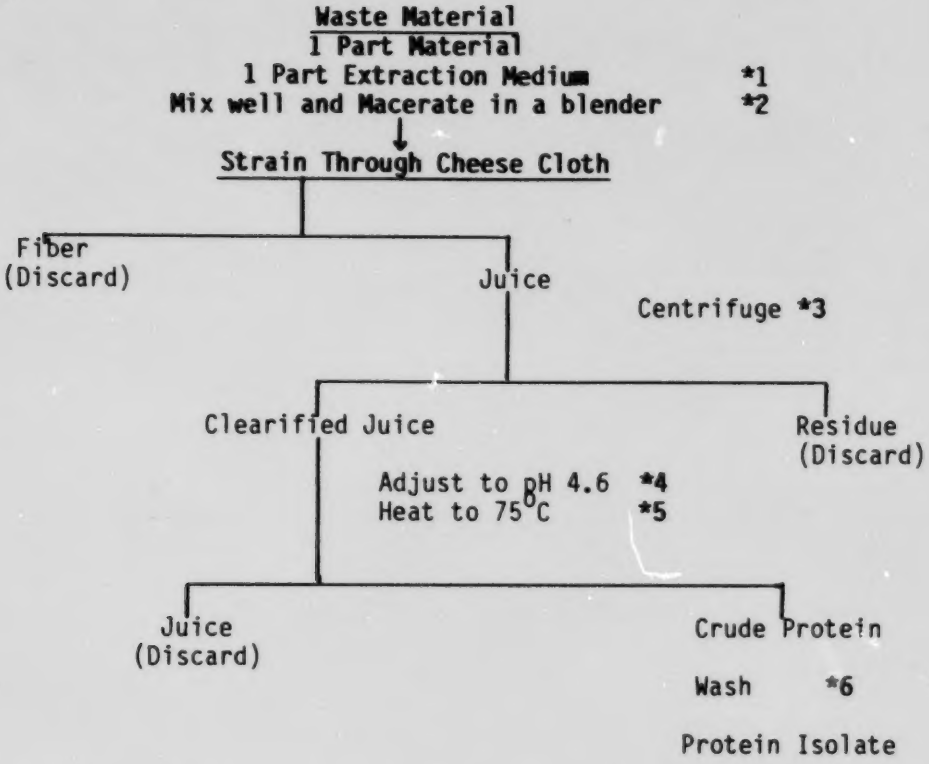
In many nations the nutrient that limits the attainment of full genetic potential is protein. Not only is high quality protein relatively scarce but it is also extremely costly. Often a poor quality protein source provides the majority of protein these people consume. Many novel protein sources have been investigated. Some of these include alfalfa, yeast protein concentrate, honey bee protein, pigweed, etc. Almost any plant or animal is a potential source of protein. The problem is to discover one that is economical, of high nutritive value and can be easily incorporated into existing food products to increase their nutritive value.

PROBLEM

Evaluate the nutritional and functional quality of protein that can be extracted from a currently under-utilized resource. This resource might well be a by-product of current food processing, e.g., blood, tomato waste, potato waste, etc.

MATERIALS AND METHODS

A protein source can be extracted to recover the protein with an appropriate buffer or solvent. A possible extraction scheme might look something like this:



*1 The ratio of Waste Material to Buffer may be varied to optimize the procedure.

*2 The Medium may be water, salt, and may be pH adjusted. As a suggestion, first try to adjust the pH of the Macerated Material to about 8.0

*3 Whatever speed is available will probably be acceptable; 1,000 to 10,000 x G is suggested.

*4 As a suggestion, try 4.0, 4.5, 5.0, etc., and see which gives the best yield.

*5 May be adjusted higher for increased yield or lower for better functionality.

*6 You may try water at ph 4.6, alcohol, acetone, etc. It will depend upon the nature of your material how much washing you must do. Try to obtain a white, bland-smelling powder. The less treatment necessary to achieve this, the better.

Experimentation will be required to determine conditions that give an optimum yield of purified protein at a reasonable cost. The protein can then be fed to rats to determine its ability to promote growth and to screen for possible toxic contaminants. The protein could also be evaluated as described in reference 3 for its ability to form foams, emulsions, gels, etc., to determine its potential utility in a food product.

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MAJOR ORGANIC ACIDS IN FRUITS

BACKGROUND

Organic acids are of great significance in plants. As intermediates in the metabolic processes of the fruit, these acids are directly involved in growth, maturation, and senescence. Fruit juices have a low pH, because they contain high levels of organic acids. The total acid content varies widely, from approximately 0.2% in pear juice to 0.8% in lime. Some of the major acids in fruits include citric, malic, and tartaric acids. Organic acids also influence the growth of microorganisms in fruit juices and therefore affect the keeping quality of the product. At proper levels certain acids are inhibitory to most bacteria. Another aspect of organic acids is their influence on the sensory properties of juice products. Acids are responsible for the fresh, tart taste of fresh fruits and their processed products. Color is also related to the type and level of acids present in the product.

PROBLEM

Identify the major organic acids in various fruits by paper chromatography. What are the major organic acids in grapes, apples, and strawberries? Do the organic acids differ between varieties of strawberries or grapes? Between varieties grown in the midwest versus California? Between grapes grown in a warm versus a cool climate? If so, why?

MATERIALS AND METHODS

Chromatographic jar: a "one-gallon mayonnaise" jar with lid is suitable for this technique.

Chromatographic paper: the paper should be designated for "chromatography" and cut into 20 x 30 cm rectangles. Whatman No. 1 or Schleicher and Schuell No. 2043 chromatographic paper is suitable for this technique.

Graduated Cylinders: 100 and 25 ml graduated cylinders are used in measuring reagents for the chromatographic solvent.

Indicator Solution: this indicator solution is used in the chromatographic solvent and is prepared by dissolving 1 g of water-soluble bromocreasol green in 100 ml water.

Micropipettes: glass capillary tubes, I.D. 1.1-1.2 mm. are used to spot the wines on the chromatography paper.

Separatory Funnel: a 500 ml funnel is used in preparing the chromatographic solvent.

Solvent: to prepare the solvent for this chromatographic technique, transfer the following into the separatory funnel: 100 ml water, 100 ml reagent grade n-butanol, 10.7 ml reagent grade concentrated formic acid and 15 ml indicator solution. Then, thoroughly shake the solvent mixture and allow two layers to form. The lower layer is discarded (aqueous phase) and the upper phase is saved to develop the paper chromatogram. Although this solvent can be used more than once, it is advisable to transfer the solvent to the separatory funnel periodically to remove any additional aqueous phase.

PROCEDURE

1. Obtain the chromatography paper (20 x 30 cm) and draw a pencil line parallel to the length of the longest side of rectangle (30 cm) about 2.5 from the edge.
2. Draw into the micropipette by capillary action a sample of juice.
3. Touch the pipette to the paper on the pencil line and make a spot about 1 cm in diameter.
4. Repeat the step for each juice to be tested, about 2.5 cm apart.
5. When the spots are dry, staple the short edges of the rectangle to form a cylinder. The edges should not overlap.
6. After adding 70 ml of the solvent to the chromatography jar, place the paper cylinder into the jar with the spotted edge towards the bottom and secure the line.
7. When the solvent has ascended to near the top edge of the paper cylinder, remove the paper and place it in a well-ventilated area.
8. Leave undisturbed until the paper is thoroughly dry, yellow spots on a blue background.
9. In order to identify these spots as to specific organic acids, the Rf value of each acid should be determined.
10. Measure the distance that the solvent traveled, from the pencil line to the solvent front.
11. Then measure the distance between the center of each acid spot and the pencil line.
12. The Rf value is calculated by dividing the measured distance of the solvent front into that measured for the acid spot.
13. Each organic acid will have a different Rf value, such as succinic acid (0.78) lactic acid (0.75), malic acid (0.5), citric acid (0.45) and tartaric acid (0.26).

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PROTEIN-FORTIFIED WHOLE-WHEAT BREAD

BACKGROUND

There is evidence that the American diet has an inadequate amount of fiber and that the incidence of a number of medical disorders, including colon cancer and diverticulitis, could be reduced if the fiber content of food were to be increased.

Whole-wheat flour adds significantly to the fiber content of bread in comparison to flour containing little or no bran at all. However, the texture of bread made entirely with whole-wheat flour is poor, because the dough fails to rise sufficiently to produce the required foam-structure. For this reason, bread baked with whole-wheat flour is not popular and the usual recipes call for using a mixture of whole-wheat flour with regular flour. The difficulties are related to a particular weak air-cell wall in dough made from whole-wheat flour causing an escape of carbon dioxide from the air-cell matrix during proofing and baking of the bread. The gas escape causes a partial collapse of the loaf.

PROBLEM

Produce a bread made with whole-wheat flour in which the air-cell matrix has been strengthened by the addition of a suitable film-forming protein.

MATERIALS AND METHODS

The baking experiments can be performed in the home or school kitchen. For your experiments, select the best whole-wheat bread recipe from your favorite cook-book and use this as your control.

For the experimental samples, using your control recipe, incorporate one of the following food proteins, either singly or in combination, replacing a part of the whole-wheat flour:

calcium caseinate
sodium caseinate
whey protein concentrate
soy protein isolate.

Samples of proteins can be obtained by calling reference 5, or the local food brokerage firm.

The addition can be made by blending the dry protein powder with flour up to a replacement (ranging from 1 to 10%). The addition of protein may produce a somewhat "stiff" dough, and more water addition may be required to obtain a dough with a workable consistency. A possible guideline may be to add 10-15 ml water for 1 gram protein added.

Measure the following parameters of the baked breads: weight of dough, weight-loss upon baking, height, weight and volume of the baked product. The volume of bread can be measured by the displacement method but instead of using water, use mustard seeds or rape seeds. Calculate the density of the breads and determine the improvement in loaf-volume as a function of protein-addition and kind of protein.

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THE SCIENCE OF MEAT CURING

BACKGROUND

The science of food processing is intriging and it is challenging. Although meat processing is commonly practiced in industry and because it is not clearly understood by the majority of consumers, it stimulates tremendous curiosity. Meat curing is an example of meat processing procedures and daily we enjoy the results.

A traditional red color is associated with cured meat in products such as smoked ham, bacon, and weiners. A brown color develops as fresh "uncured" meat is cooked. The principle difference is that the red product has been cured. The color of meat is dependent upon the muscle pigment known as myoglobin just as the red color of blood comes from the pigment called hemoglobin.

Fresh pork may be cured for the purpose of preservation but of greater importance today is the pleasing palatability and the variety in our diet which cured pork provides. A study of curing agents is fascinating. Salt adds flavor, slightly dehydrates the meat and has a preservative effect through its dehydrating action on bacteria. A sweetening agent may be used to contribute flavor. The compounds resulting from sodium nitrite reduction react with myoglobin, the muscle pigment, to establish the color change from the grayish pink color of fresh pork to the red color of cured pork. A few speciality items are cured by applying the dry ingredients to the surface of the meat. These dry ingredients go into dilution with the normal moisture in the meat and permeate through the piece by means of osmosis. Modern technology suggests dissolving the curing ingredients in water and injecting them into the meat for rapid and controlled processing.

PROBLEM

This project is designed to investigate one method of pork curing with the amount of sodium nitrite and temperature as variables. What are the differences in color change when sodium nitrite or temperature are changed? Is there a difference if sodium nitrate is substituted for sodium nitrite?

MATERIALS AND METHODS

Cubes of fresh pork, measuring 5 inches or more on a side, from the fresh ham or shoulder, serve the purpose. Prepare curing mixtures using these formulas: 25.0 grams salt (NaCl), 9.0 grams sweetening agent (brown sugar), .025, .05, 0.1 or 0.2 grams sodium nitrite. To assure uniform distribution, mix dry ingredients, and finally add moist or sticky ingredients such as brown sugar. (An alternative to obtaining each curing ingredient and mixing them is to use a commercial curing mixture available in some stores. One such product is Morton's Sugar Cure.) Rub the curing mixture over the surface of the pork cube at the rate of 25 grams per pound of pork meat. Store each cube in a glass or plastic container at approximately 40° Fahrenheit. As an alternative experiment, store each cube at room temperature. Apply the curing ingredients to a different cube of pork on successive days so that on a given day you can, by cutting the cubes in half, show the changes that occur in 24, 48, and 72 hours as the myoglobin is converted to nitrosomyoglobin.

Heating the pork to 150°F will produce the characteristics of cooked pork and convert the nitrosomyoglobin to nitrite oxide hemochrome, a more stable pigment. This will terminate color development and stablize the color contrast. Protect the finished product from light and oxygen to inhibit color fading.

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TUMBLING OF CURED MUSCLE TISSUE

BACKGROUND

Tumbling or massaging of cured muscle tissue results when cured tissue is placed in a rotating drum (similar in construction to a small cement mixer) which picks up the tissue and drops it to the bottom of the drum or when cured tissue is placed in a vat and stirred with paddles. This procedure was developed in Europe and is currently widely used in the United States for many cured items. Its reported advantages are:

1. Increased yield in curing and cooking.
2. Increased uniformity of color.
3. Increased uniformity of curing ingredients.
4. Upon cooking, small pieces will bond together more tenaciously and upon slicing a more attractive slice will be obtained.
5. Increased juiciness of final product.

PROBLEM

Many items could be studied and an example of some of them might include:

1. Amount of cure solution the tissue will hold.
2. Appropriate temperature of tumbling.
3. Influence of tumbling time or tumbling speed.
4. Comparison of continuous versus intermittant tumbling.
5. Influence of various additives and/or level of additives.

Many items could also be measured to see the influence of the tumbling and these might include, but are not limited to:

1. Curing yield
2. Cooking yield
3. Cohesiveness of cooked slices
4. Color uniformity
5. Juiciness
6. Tenderness
7. Temperature during tumbling
8. Microbial growth during tumbling.

MATERIALS AND METHODS

To conduct research in this area a miniature tumbler or massager will be needed. This can be as simple as a container shaken by hand for 10 minutes per hour to a rotary rock polishing type device to a paddle stirrer. Some preliminary research will be needed to insure that the mechanical action does not tear up the tissue but does give it a physical manipulation.

A curing solution will also be needed and it usually consists of:

Quantity in Meat	Ingredient
20% pump	Water
2%	Salt
156 p.p.m.	Sodium Nitrite
1%	Sugar
0.5%	and sometimes phosphates

REFERENCES

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WATER BEHAVIOR IN FOOD SYSTEMS

BACKGROUND

Water is the principle component of food products. It acts as solvent, a transport medium, and contributes to turgor (firmness), viscosity (consistency), and elasticity (stiffness). When its availability is limited by addition of salts, sugars, glycols, or acids such as lactic or acetic, microbial growth is limited - first bacteria, then yeasts, molds. The rate and extent of discoloration and of enzymatic rancidity is also retarded. When such humectants are at high levels or the product is partially dried, the stability is extended as for vended snack foods, dried fruits, and cereals. At very low moistures, powders such as spray-dried milk or sauces are stable as are dried vegetables. But, the materials may become brittle, shrunken, and may not rehydrate well.

Food scientists - chemists, microbiologists, and engineers - manipulate moisture levels in conjunction with process temperature and ingredients to produce new nutritious, acceptable products. They measure the availability or "activity" of the water by measuring the relative humidity above a product in a closed container. For development purposes they may manipulate the moisture level by placing product above saturated salt solutions in a closed container.

PROBLEM

Choose any attribute you wish - e.g., growth of microorganisms (you may wish to examine one or more of the references first). Pick a product you like and can afford to work with. Then manipulate the water availability level to discover for yourself and to demonstrate to others, the result. Design the experiment with replication so you can demonstrate the validity of the work. Interpret the results based on simple biological, chemical, or physical principles. Then attempt an experiment to demonstrate that your interpretation is reasonable.

MATERIALS AND METHODS

Demonstrate how moisture availability changes with moisture level by drying (or absorbing on) clean product slices of known initial moisture on foil pans over saturated salts. Determine the weight after several days when it becomes steady.

Test your attribute - color against standards, texture by penetration or bending, viscosity by draining of a pipette or capillary viscometer, or capability of supporting microbial growth over several days storage. You might allow the natural contaminants to grow. Or you might innoculate the surface with a dilute slurry of material from moldy bread, spoiled dairy or meat products. Do not use spoiled non-acid canned vegetables! Observe the results vs. time. Quantitate the relative amount of growth, e.g., 0, +, ++, +++, ++++. Replicate several times!

You would have gotten different results if you had made gels of different initial moisture, innoculated it with organisms, then exposed it to these low humidity atmospheres. Why?

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DIMENSIONAL CHANGES IN WOOD

BACKGROUND

The dimensions of green lumber change as the moisture content is lowered by drying. Shrinkage does not begin immediately and is not equal in all directions. Dimensional change is erratic and unpredictable in certain abnormal wood samples. Wood technology is a well defined body of knowledge which allows the experienced observer to explain these phenomena.

The average person feels at home with wood products and is likely to overlook these predictable changes until problems arise because of them. Wood looks and feels dry when it actually contains a significant amount of moisture. Home workshop enthusiasts often find that further drying has partially destroyed their handicrafts.

PROBLEM

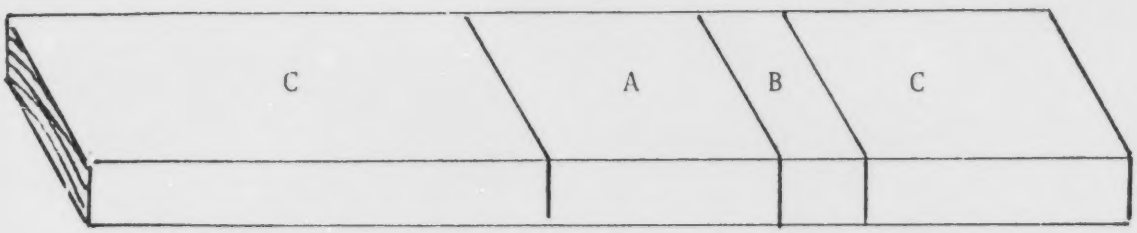
Investigate the changes in dimensions of wood samples. What changes occur overtime (i.e. at 24, 48 and 72 hours) when wood samples are taken from a high humidity environment (e.g. a green house) to a dry environment? From a dry environment to a moist environment? Are there differences in change between species of wood? If so, why?

MATERIALS AND METHODS

Measure the change in dimensions of wood samples. The moisture contents of these wood samples are also measured and correlated to the thickness, width and length measurements. High school science laboratory equipment should be adequate for carrying out all of the procedures. A moisture meter costing less than $100.00 is optional. Wood samples are readily available from local sources.

Step 1. Assemble several sample boards which will be used to prepare the demonstration pieces. These may include more than one sample board from each wood species.
Step 2. Cut the demonstration pieces as illustrated below for kiln samples.
Step 3. Weight the demonstration pieces and the companion pieces as outlined below.
Step 4. Use the smaller companion pieces to determine original moisture content.
Step 5. Measure the dimensions of each demonstration piece IMMEDIATELY and record.
Step 6. Follow the drying day by day. Weigh the demonstration pieces to determine moisture contents. Measure the changes in dimensions which accompany changes in moisture content. These will be different in each case but should follow the normal pattern explained in reference number 4 below.

Measuring Dimension and Moisture Change.



Sample A and sample B will be taken from the interior of an average board. The parts marked C will not be used as samples because of drying from the ends.

Sample A will be the demonstration piece. Measure the moisture content (MC)and the dimensions daily.

Sample B will be used to determine the moisture content of sample A -- thus providing the calculated oven dry weight.

When the calculated oven dry weight of sample A is known, daily weighing will provide moisture content information.

Let us assume that the original weight of sample B is 3.6 and that after drying to a constant weight it is 2.0 pounds. This means we lost 1.6 lbs of water. Now, 1.6 divided by 2.0 tells us that the moisture content was 80%. That is to say, the MC of sample A was 80% at the time of preparation and placement in the charge of lumber. Well, after all, it was cut adjacent to sample B and should be the same MC.

Let us assume that the original weight of sample A was 19.8 pounds at 80% mc. This 19.8 lbs is equal to 100% of the oven dry weight plus 80% of the oven dry weight. Right ??? Right !!!! That is to say 19.8 lbs is 180% of the oven dry weight. Sooooo -- 100% of the oven dry weight is 11.0 pounds.

Let us assume that after two weeks in the predryer sample A weights 16.3 pounds. We can now calculate the moisture content by subtracting 11.0 from 16.3 --- then dividing the remainder 5.3 by the oven dry weight 11.0. The result is 48%MC.

This can be repeated day by day until you reach the desired moisture content. More than one sample should be used to provide increased accuracy.

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EFFECTS OF DIFFERENT NUTRIENTS ON SATIETY

BACKGROUND

Although people in many parts of the world are starving or malnourished, the biggest nutritional problem in Western society is obesity. To a great extent, appetite controls food intake. Fats, carbohydrates and proteins do not have equal caloric density; fat has 9 Cal/gm while carbohydrates and proteins each have approximately 4 Cal/gm. Fat has long been known to have a high satiety value. Is that because it has more calories/unit weight or because its chemical composition triggers some specific reaction in the body?

PROBLEM

The purpose of the proposed study is to attempt to determine whether the high satiety value of fat is due to its nutrient density or to its chemical composition.

MATERIALS AND METHODS

This project will necessitate using laboratory rats and must employ safe and ethical laboratory procedures. At no time during these experiments will any of the animals suffer unnecessary stress and none of the procedures will involve any pain to the animals.

This experiment will require separate cages for the animals, a balance accurate to .1 gm and accurate and careful record-keeping.

This experiment can be accomplished using meal-fed rats which have been trained to consume their daily ration in a set period of time (3 hrs.). Thus, a two-week acclimation period will be required to train the rats. First, rats are randomly assigned to one of three groups. At the same time each day, a weighed amount of food is offered to each rat individually for 3 hrs. At the end of the three-hour period, the food cups are removed and the food is reweighed in order to calculate the daily food consumption. Rats must be weighed daily during this period to accustom them to the procedure. By knowing how many calories/gm the food contains (usually available from the manufacturer), it is possible to calculate the daily food intake.

In the second part of the study, weighed amounts of food will be offered to the rats for 30-min. then removed from the cages and reweighed. At this time .5cc of fat (corn oil) or sugar solution (sucrose) or protein solution (casein) is injected into the rat's mouth using a calibrated eye dropper. Then the normal food is returned to the cage for the rest of the three-hour eating period after which the food is weighed again. The total calorie intake/day can then be calculated taking into account the calories injected into the rats' mouths. Rats should also be weighed daily to determine whether there is a significant difference in weight gain between the groups. If the satiety effect of fat is merely a function of its greater caloric density then the total calories consumed by each group will be the same. If fat induces satiety by a chemical means, then less calories will be consumed by the group receiving corn oil.

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ATTRACTIVENESS OF NOCTURNAL INSECTS TO LIGHT OF DIFFERENT WAVELENGTHS

BACKGROUND

The attractiveness of light to night-flying insects has been known since cavepersons began using fire. More recent studies have shown that different kinds of insects are preferentially attracted to differing wavelengths of the spectrum. Plant-feeding species, for instance, are attracted to green. Some of this information is utilized in the design of insect traps, which are used both to monitor insect activity in the field as well as to attract insects and (sometimes) kill them be means of an electric grid. There is still much information to be gained on the attractiveness of specific colors to insects and a student undertaking this project is likely to discover some presently unknown facts about some common insects.

PROBLEM

Determine whether different kinds of insects show a preference for light of a particular color.

MATERIALS AND METHODS

Place red, blue, yellow, green and white incandescent light bulbs on extension cords at least 10 feet from the nearest building and 20 feet from one another.

Make a record of the different insects that come to each color. You may wish to make a small collection - directions can be found in some of the references listed. The references are also useful for identification of the insects you find.

The warmer the weather, the more successful this project is likely to be because insect activity slows at air temperatures below about 50°F. However, night-flying insects are common in Ohio from mid-March to early November.

You may wish to change the location of each color nightly as a check against slight differences in environment. For instance if one bulb is under a tree and another in the open, the one under the tree is more likely to attract tree crickets regardless of color.

Exercise caution with electrical equipment outdoors. In particular do not sample while it is raining and be careful if the ground or vegetation is damp.

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EFFECT OF TEMPERATURE ON INSECT GROWTH AND DEVELOPMENT

BACKGROUND

Insects are "poikilothermic"; that is, the insect's body generally takes on the temperature of its environment. They are often called "cold-blooded" though this is imprecise because their blood becomes warm in a warm environment. As the insect's body processes are at the mercy of outside temperatures, one might expect that growth and development would be retarded by low temperatures and enhanced by high temperatures.

Aquatic insects are ideal subjects to illustrate the impact of temperature on development for they are especially at the mercy of their environment. (Terrestrial species can often raise their body temperature significantly by appropriate behavior - shivering, sitting in the sun, etc.) Mosquito larvae, called "wigglers," are aquatic (though they breathe air from the water's surface) and most species feed on microscopic plants and detritus found in stagnant water everywhere. Mosquito pupae are also aquatic, and active, though they do not eat.

PROBLEM

Determine the relationship between environmental temperature and development of an insect.

MATERIALS AND METHODS

For this experiment you will need 3 to 5 shallow pans (cake pans, pie plates, or photographic darkroom pans will do), window screening, a thermometer, and a source of mosquito larvae. These can usually be found anywhere there is water standing for longer than 10 days. Streamside puddles, old tires, ponds, birdbaths, etc., are good sources. You can also attract them by placing pans of water near dense vegetation anytime between March and November.

Fill each of your experimental pans with about one inch of the same water from which you obtain the mosquito larvae. Place 20-25 larvae in each pan. Tightly cover each pan with window screening. It is best to secure it with masking tape.

Place each pan in an environment with a different temperature. Suggestions are: a refrigerator (with permission, of course), a cellar, a garage, a warm and sunny place indoors or outdoors. Observe the larvae daily and record changes as they occur. Note especially the appearance of pupae, (recognizable by the bulging anterior containing the developing legs and wings) and emergence of adults. Determine the relationship between time of development and temperature. Make an effort to control other variables as much as possible; light, for instance, will differ between a cellar and outdoors. So will air movement.

NOTE: This project can be adapted to using grain-feeding insects. Details of their rearing are in the next project entitled: "Population Growth and Food Limitation." They can be grown in light-tight containers, thus controlling for light and air movement.

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3. The Insects. Chicago: Time-Life Books, 1962.

4. Articles on "Insects" and "Mosquitoes" in World Book or Academic American Encyclopedia.

5. Leaflets on mosquito biology are available through your County Cooperative Extension Service Office.

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POPULATION GROWTH AND FOOD LIMITATION

BACKGROUND

Are animal populations limited by their food supply? This has been argued for almost two hundred years since Thomas Malthus published his famous essay on the growth of human populations.

Grain-feeding insects are an ideal subject for study of population growth and limitation. They are easily obtained and very easily raised in laboratory or home. In fact, most species are pests and people spend a great deal of effort in attempts to eliminate them. If given sufficient warmth they can produce 3 or 4 generations during the length of an average science project.

PROBLEM

The hypothesis is that grain beetle populations grow larger under conditions of unlimited food.

MATERIALS AND METHODS

The most appropriate insects for use in this project are the confused flour beetle (Tribolium confusum) or the saw-toothed grain beetle (Oryzaephilus surinamensis). Ask around for an infestation; grain dealers, feed stores, petshops - someone is bound to have one or both infesting any dried foodstuffs. Bird seed or pet food are especially likely places. The larger mealworm, Tenebrio molitor, available at most pet shops, is not suitable because it grows too slowly, though a pet shop that raises mealworms is likely to have the others contaminating its mealworm culture.

The beetles have complex metamorphosis: egg, larva, pupa, and adult. They can survive on almost any dried food or vegetable origin though do best on dried breakfast cereal, cornmeal, or oatmeal.

Set up an equal number of beetles in each of several glass or plastic containers with tight-fitting lids. (Baby-food jars are excellent.) Place a measured amount of food in each. (The precise amounts are up to you.) Put the covered containers in a warm but dark place ($80^{o}F$ + $90^{o}F$ is best) for 6 to 8 weeks. Check periodically on your culture's progress but do not add food. At the end of the period, count the surviving larvae, pupae, and adults in each container. (Eggs are very hard to find.)

As a check that food rather than space is limiting beetle populations, set up a companion experiment with your standard number of beetles and lowest amount of food in each of several containers varying in size.

CAUTION: You need not poke holes in jar tops. Unless you are a muscleman you won't close the jars tightly enough to seal out fresh air. More importantly, it is well to keep the beetles in the containers, so that they do not move between containers and confuse your censuses, nor go off to colonize food in your kitchen.

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2. Insect Pests, Golden Nature Guides. New York: Garden City, 1966.

3. Malthus, T.R. "An Essay on the Principle of Population." (has been reprinted in numerous editions).

4. Leaflets on biology of grain beetles are available through your County Extension Office.

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THE INFLUENCE OF TEMPERATURE ON POLLEN GERMINATION AND POLLEN TUBE GROWTH

BACKGROUND

The various stages of normal plant growth and development are strongly affected by temperature. Higher plants generally reproduce by sexual union of the microgametes (sperm) and megagametes (egg) to produce a new embryonic plant, the seed. The seed may be enclosed in a fleshy covering and the entire organ is called a fruit. Generally, for fruits to develop normally there must be pollination, fertilization and subsequent seed development. If any of these processes do not occur, fruit set and development will not occur. The process of pollination, pollen germination, and pollen tube growth must take place first.

Pollen germination and pollen tube growth are greatly affected by temperature. Studies have been made on structure, chemistry and physiology of pollen and the culture of pollen in vitro. Various culture solutions have been proposed including the necessity for certain nutrients in the media.

PROBLEM

Determine the influence of temperature on pollen germination and pollen tube growth.

MATERIALS AND METHODS

1) A source of pollen -- tomato or cucumber plants; 2) Controlled temperature chambers of about 10°, 21°, and 38°C; 3) Culture media--10% sucrose + 100 ppm Boron*; 4) Microscope slides, petri dishes, filter paper, dissecting needles, microscope, 0.25% w/w thionin** stain in distilled water.

Place 2-3 drops of the culture media onto a microscope slide and carefully add pollen. (Pollen may be collected on the tip of a dissecting needle after splitting open the anthers of the flower with the needle.) Place the slides on moistened filter paper in petri dishes and place into the temperature chambers.

Observe the pollen germination under the microscope after 1/2, 1, 2, and 3 hours. In order to see the pollen tubes more clearly, stain the preparations using 1 or 2 drops of thionin stain before observation under the microscope . Most pollen tubes can be observed under the lowest power of most micoscopes.

Record the number of pollen grains that have germinated, number aborted (bursted without tube growth), and number not germinated, so percentages can be calculated. Also, compare the rate of growth of the pollen tubes under all temperature regimes.

NOTE: In vivo pollination effects can also be studied on the plants by pollinating some flowers and not others and observe results.

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1. Maheshwari, P. An Introduction to the Embryology of Angiosperms. New York: McGraw-Hill, 1950.

2. Any good botany textbook.

3. Several Chapters in Annual Reviews of Plant Physiology 15 (1964): 255-270 and 19 (1968): 435-462.

* Boron from Boric Acid available at local pharmacies.

** Thionin biological stain available from several scientific chemical suppliers including Curtin Matheson Scientific, 12101 Centron Place, Cincinnati, OH 45246 (513-671-1200), or 4540 Willow Parkway, Cleveland, OH 44125 (216-883-2424). Local hospital laboratories may also have small amounts available.

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PLANT TISSUE CULTURE

BACKGROUND

Plant tissue can be stimulated to reproduce whole plants under appropriate environmental and cultural conditions. The plant produced by rooting a stem or leaf cutting is a clone of the parent plant and the process is termed vegetative or asexual propagation, or simply cloning. Clones are genetically identical to each other and to the parent plant. Clonal populations are reliably uniform in growth, yield, flowering, disease resistance and other important features which may be variable in seed or sexually propagated populations.

Plants can be cloned by rooting cuttings, layering, grafting, or by dividing specialized reproductive structures such as bulbs, tubers, rhizomes, or runners. Multiplication in tissue culture is much more rapid. Tissue culture involves taking a small piece

of plant tissue and placing it in a sterile environment on a medium which contains all the nutrients required for rapid growth and development. The key ingredients which determine the pattern of growth and development are the plant growth regulators, auxin and cytokinin. Auxins (2,4D, naphthaleneacetic acid, indoleacetic acid, indolebutyric acid) promote root development. Roughly equal mixtures of auxin and cytokinin together generally promote unorganized growth (callus growth).

Success in regenerating plants from isolated tissues is dependent upon several factors: 1) the appropriate type and concentration of plant growth regulators for the medium must be identified for the plant in question; 2) a suitably responsive tissue must be found; and, 3) the tissue must be established in culture under sterile conditions. After plants are produced in culture, similar experiments must be carried out to root these and establish them into greenhouse conditions.

PROBLEM

The specific technique used to demonstrate regeneration of plants in tissue culture varies somewhat depending on which species is used. Experimental variables for the development of the system may include: 1) the tissue culture medium to be used: 2) the tissue to be used as an explant (leaf, flower, shoot tip, root, etc); and, 3) the appropriate means for rooting the plants produced. African violet leaf tissue is recommended as a suitable starting point.

MATERIALS AND METHODS

Prepared tissue culture medium is commercially available in a variety of forms and recipes. Some of these do not have growth regulators already added and thus can serve as a starting point for investigations of the effects of the various growth regulators on plant development. Tissues from different parts of the same plant, the same part of a plant at different stages of growth, or the same plant part at different times in the year may respond very differently to the same medium and physical environment. Light, temperature, and daylength may affect the development of plants in culture. The student must remember that whatever the nature of the project, the first stage involves searching the published literature for all available information concerning the plant, and any attempts which have been made to tissue culture it.

REFERENCES

Since a small amount of information is available in the popular literature concerning plant tissue culture, contact the author at the address below for a packet of information and some hints about where to start.

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ETIOLOGY OF MAIZE DWARF MOSAIC, A VIRUS DISEASE

BACKGROUND

Etiology (the science of disease causation) is a fundamental concept in pathology (the science of disease). Etiology as a concept is used by plant pathologists, physicians and veterinarians. Application of the concept depends upon the nature of the pathogen (bacterium, fungus, virus, etc) and the diseased organism (plant, animal or human).

Viruses pose a particular challenge in demonstrating etiology because of their extremely small size (about 10^{-5} to 10^{-6} of an inch for plant viruses) and, in some cases, a form that is nearly indistinct from normal cellular constituents, namely ribosomes. Also, in some cases they occur in such low concentration that they escape detection by conventional methods. Not only are viruses extremely small but many, particularly plant viruses, are chemically very simple being composed of nucleic acid, RNA for most of these viruses or DNA (either of which contains the genetic message) and protein which forms a covering made of many identical subunits encasing and protecting the nucleic acid.

In demonstrating the etiology of a disease a set of principles, called Koch's postulates, are followed. These were formulated by German microbiologist Robert Koch in 1895 and as adapted for virus diseases, are simply stated: 1) the putative pathogen (virus) must be constantly associated with the disease; 2) the virus must be isolated from the diseased organism and obtained in pure form; 3) the purified virus when introduced (inoculated) into a healthy organism of the same species as that from which it was originally obtained must produce symptoms identical to those seen in the organism from which it was isolated; and 4) the virus must be isolated and purified from the diseased organism that was experimentally inoculated and the purified virus must be shown to be the same as the pathogen isolated from the initially diseased plant.

To demonstrate the etiology of a virus disease the researcher must have the means to detect, isolate, purify and inoculate the virus and to show that it is identical in different infected individuals of the same species showing similar symptoms.

Viruses infecting plants are particularly convenient for demonstrating viral disease etiology. First, they are safe to work with in that they will not infect the investigator. Secondly, if the virus is carefully selected, one can be found which is easily handled and which will not be easily transmitted to other plants that the investigator wishes not to infect. Thirdly, if a plant species that is easily grown is chosen, the investigator has little trouble in maintaining healthy and diseased plants for experimental work. One such host-virus combination that possesses the above desirable features is corn (maize) infected with the maize dwarf mosaic virus (MDMV).

PROBLEM

Establish the etiology of a diseased corn with maize dwarf mosaic-like symptoms.

MATERIALS AND METHODS

To establish this will require plants with virus-like symptoms and application of Koch's postulates as adapted for demonstrating viral etiology. The demonstration will require that the investigator learn methods to detect, isolate, purify and inoculate MDMV and to show its identity when infecting different corn plants.
A list of references that describe the methods needed in this project are listed below.

These references will also list the materials needed and for those not obtainable in your high school alternate sources will need to be found. Finally, a source of virus-infected corn will be required. All of the above items, (references, sources of materials, and infected material) may be obtainable by writing to the author at the address given below.

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FACTOPS INFLUENCING DAMPING-OFF OF GARDEN PEA BY PYTHIUM ULTIMUM

BACKGROUND

When a seed is planted in field soil and sufficient moisture is available, the seed will germinate and a young seedling plant will emerge. In every gram of field soil there are millions of microscopic organisms. The most prevalent of these are bacteria, but a second group, the fungi, are also present. Some of the fungi can penetrate and grow into a young seedling plant and kill it. This disease is called damping-off. One of these fungi, Phthium ultimum, is found in almost all soils (in Ohio) and is extremely effective in killing seedlings. The common garden pea is very susceptible to Pythium damping-off and has been very useful as a test plant.

PROBLEM

Determine the influence of environmental factors, including the presence of toxic chemicals, on damping-off of garden pea by Pythium ultimum.

MATERIALS AND METHODS

To initiate the research project, a batch of soil that is heavily infested with Pythium ultimum is needed. The soil in the borders of your back yard or from almost any source is infested with Pythium. However, since the fungus has not been growing rapidly, by killing seedlings for example, the amount of the fungus is not great. Put some of the soil in culture pots or in any container that has some drainage. Plant untreated garden pea seeds, water heavily and let the seedlings grow. Most of the seedlings will grow normally,

but a few will damp-off and die, either before or just after emerging from the soil. Count the seedlings that have emerged, then dump the soil into a container, screening out the seedlings and rotted seeds. Use the same soil to plant more garden peas. This time a much greater number of the seedling will die before emerging from the soil. This has happened because the soil is now heavily infested with Pythium. If you wish to see the Pythium, put some of the rotted seedlings in a moist paper towel or napkin. Keep the paper wet by placing it in a closed container. The next day you can see a white mold growing out of the rotted seeds. This white mold is Pythium.

Using the soil that is heavily infested with Pythium, a number of experiments can be designed to determine the influence of environmental factors on Pythium damping-off of garden peas. The following are examples:

1. Determine how cooking the soil at different temperatures influences damping-off. For example you might heat the soil in an oven at 100°F, 160°F, and 230°F for 10 minutes. Let the soil cool and plant seeds. You may want to vary the length of time of cooking the soil.
2. Determine how the amount of water added to the soil after planting seeds influences damping-off.
3. Determine how diluting the heavily infested soil with natural soil (not heavily infested) influences damping-off.
4. Determine whether treatment of infested soil with chemicals known to be toxic to microorganisms can reduce damping-off. Perhaps the seeds should be treated rather than treating the soil. Some toxic chemicals commonly found in the home are chlorox, ammonia, rubbing alcohol, and mouthwash. Pesticides commonly used in the yard are weed killers, insecticides, and fungicides such as captan and benomyl.

In designing an experiment always remember the principles of control and replication. In an experiment to determine how cooking the infested soil influences damping-off, you may have found that 70% of the seeds germinated normally when planted in soil that had been cooked at 200°F for ten minutes. Without the control, determining percentage germination in soil that had not been cooked, you have no way of evaluating the influence of the treatment. Perhaps 70% of the seeds would have germinated if the soil had not been cooked at all.

Suppose you heated the soil in one pot at 200°F for ten minutes and after cooling of the soil planted ten seeds. In another pot with soil that had not been heated you also planted ten seeds. Assume that 7 seedlings grew in the soil that had been cooked and 4 in the unheated soil. No conclusions can be drawn. The difference detected here may be due to natural variation which always occurs when working with biological systems.

Replication is needed.

Addendum

Damping-off is one of the most common diseases of plants and Pythium frequently causes this type of disease. However, there are many other fungi that can cause damping-off. Garden pea, like many other plants, must have a fungicide powder placed on the seeds to protect them against damping off. This routine seed treatment with a fungicide like captan is very effective in preventing damping off.

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PROOF OF PATHOGENICITY OF HELMINTHOSPORIUM MAYDIS IN SOUTHERN CORN LEAF BLIGHT DISEASE

BACKGROUND

Symptoms of plant disease can be caused by infectious agents such as fungi, bacteria, viruses or mycoplasmas. Alternatively, non-infectious agents can be involved. These include high or low temperature stress, atmospheric pollutants (ozone, sulfur dioxide, acid rain) and soil contaminants (toxic organic wastes, heavy metals).

In order to control plant disease or injury it is usually necessary to identify the cause. To do this standard procedures are used by plant pathologists. When an infectious agent is assumed to be responsible for plant disease symptoms proof of this is obtained by following the general rules first outlined by Robert Koch as follows: (1) a specific organism must always be associated with the disease, (2) the organism must be isolated in pure culture from the diseased host, (3) the isolated organism must produce the characteristic symptoms of the disease in the host and (4) the same organisms must be re-isolated from the artificially inoculated host.

PROBLEM

Demonstrate that Helminthosporium maydis (Bipolaris maydis) is the cause of a leaf disease in corn using rules outlined by Koch.

MATERIALS AND METHODS

Materials: Corn (Zea mays L.) plants (2-3 wks. old) that have been inoculated with H. maydis and have lesions (6-10 days old); young potted corn plants (2-3 wks. old); 10% solution of clorox; petri dishes of potato-dextrose agar (PDA); sterile water blanks; platinum loop; forceps; razor blade; sterile filter paper or blotting paper; Tween 20, Tween 40 or liquid soap (detergent); atomizer spray.

Methods:

1. Isolation of Helminthosporium maydis: Select leaves with lesions on an inoculated corn plant. Cut several leaf pieces with lesions from these infected leaves using a sterile razor blade and sterile forceps. Immerse the leaf pieces in a vial with the 10% clorox solution for 10 seconds. Transfer leaf pieces to fresh vial with sterile distilled water. Transfer to sterile blotting paper to remove excess water then transfer to petri dishes with PDA. Incubate petri dishes (in an inverted position) for 7 days in the dark at 24 to 28°C. Check plates for presence of colonies at 3-day intervals. Compare colonies with valid cultures of H. maydis. Transfer a portion of a typical colony to a fresh petri dish with PDA. Incubate for 10 days.

2. Observation of fungus isolated from infected corn leaves: With a sterile platinum loop scrape off a surface portion of a typical colony and transfer to a drop of sterile water on a microscope slide, then add a cover glass to the water drop. Examine the preparation under the compound microscope using a 10X objective. Fungal hyphae and spores with a distinctive morphology should be seen.

3. Inoculation of corn plants with H. maydis: Prepare a spore suspension (20,000-30,000 spores/ml) using one or more 10-day old PDA cultures of H. maydis. To do this use sterile distilled water containing Tween 20 or liquid soap (0.1 ml/100 ml). Flood each petri dish with the fungus with 10 ml distilled water and Tween 20. Gently scrape the flooded petri dish with a transfer loop to release the spores. Pour the spore suspension into a beaker, then estimate the number of spores per ml using a hemacytometer or by counting the number of spores in suspension on a glass slide and cover glass, per microscope field with the objective set at 10X. Adjust the volume so that the spore suspension is about 20,000 spores/ml. If a glass slide and cover glass is used prepare a suspension to give 20 spores per microscope field then dilute by adding 4 parts distilled water + detergent to one part of spore suspension. Apply this diluted spore suspension to 2-3 week old potted corn plants using a spray atomizer. Cover inoculated plants with clear plastic bags for 72 hours to maintain high relative humidity during early stages of infection. Keep plants in greenhouse or growth chamber at 28°C for at least 12 hours per day following inoculation. Remove plastic bags at the end of the 72 hour period. For the next several days maintain the inoculated plants under favorable

conditions of watering and light at 22-28°C. During this period observe corn leaves for development of characteristic lesions and blight symptoms.

4. Reisolation of H. maydis from the infected corn leaves: After leaf lesions have appeared on corn leaves inoculated as described above, repeat methods described in (1) and (2).

Helpful Notes:

1. Precautions: Use asceptic technique. Make sure to keep spores of H. maydis in suspension during inoculation. Spores tend to settle to the bottom on a container if suspension is not agitated. Inoculation of corn plants with spore suspensions should be accompanied by use of appropriate controls; e.g. spray similar corn plants with distilled water and Tween 20 solution lacking spores of H. maydis. Do a test inoculation of corn plants to get confidence in your procedures. Use lesioned leaves from test inoculation to do steps 1-4 in "Methods" section above.

2. Time required: Four-five weeks for completion of experiment; 8-12 hours to prepare media and complete experimental work.

3. Results: With the use of the above procedures, colonies of H. maydis should be isolated readily from infected corn leaves. The fungus on PDA should show dark to black mycelium and dark elongate segmented spores with 3-6 cross walls. The spores germinate in 3-4 hours with germ tubes emerging from either end. The fungus is also called Bipolaris maydis because of this bipolar mode of germination. Symptoms should include several leaf lesions which vary in size from 2-4 mm. Varying degrees of chlorosis should be seen. Leaf browning or blighting will be evident in the later stages of the disease. The fungus isolated from leaf lesions should have the same characteristics as that used in the initial inoculations.

4. Availability of materials:

Corn seed - any seed company will supply, e.g. The Ohio Seed Co., P.O. Box 598, West Jefferson, OH 43162 (614-879-8366).
H. maydis cultures - available from American Type Culture Collection or write to author of this project.
Potato dextrose agar - a popular source is Difco Laboratories, Detroit, Michigan.

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"OPTIMUM" NUTRIENT CONCENTRATIONS FOR GROWTH OF TREE SEEDLINGS

BACKGROUND

Survival and growth of tree seedlings, as well as other plants, are affected by varying levels of soil fertility. At levels below the "optimum" for a specific species, growth is reduced. At levels above the "optimum", top growth may be excessive in relation to root growth. This results in plants having unfavorable top-root ratios (top weight/root weight) which are less adapted to unfavorable environmental conditions, particularly low soil moisture levels.

Different tree species may vary considerably in the total nutrient concentrations at which optimum growth occurs. However, research by Ingestad (reference below) has shown that many species show best development when grown in nutrient solutions or soils having the same ratio of essential plant nutrients (i.e. ratios of N to P to K to Ca, etc.).

PROBLEM

Determine the rate of survival and growth of tree seedlings when grown using nutrient solutions having different total concentrations but the same ratio of essential plant nutrients.

MATERIALS AND METHODS

For demonstration purposes, tree species chosen for planting should be relatively fast growing. Suggestions include Virginia pine (Pinus virginiana) or shortleaf pine (Pinus echinata) which have relatively low nutrient requirements or one of the broadleaved species such as red maple (Acer rubrum) or tuliptree (Liriodendron tulipifera) which generally have somewhat higher requirements. For comparison, one species from each group might be used. A source of seed is listed in reference 3 below. Tree seedlings should be grown from seed in a porus, inert, sterile potting medium such as silica sand. Seed can be germinated in pots (2 to 4 per pot)

or in separate containers and transplanted to pots shortly after germination. Seedlings should be "watered" with Ingestad's nutrient solutions made up using distilled or demineralized water. To show growth response over a range from sub-optimum to at or near the toxic level, at least 5 and preferably 10 different solutions should be used with concentrations ranging from approximately 25 to 1000 ppm. Chemicals and proportions of each needed to prepare nutrient solutions are listed in the table below. Solutions of varying levels should be added to pots periodically to keep the potting medium moist at all times. Trees should be grown in a sunny location or under light (preferably a mixture of incandescent and fluorescent) with a minimum intensity of 1500 foot candles and a minimum 18 hour light period to keep seedlings growing more or less continuously. When trees have reached sufficient size, a representative sample from each group should be "harvested" and measurements made of tops and roots, including lengths, weights (oven-dry) and shoot-root ratios. For exhibit purposes, living seedlings can be presented, along with data in tabular and/or graphic form.

Table 1. Mixtures of chemicals for preparing two nutrient solution concentrates for use in fertility studies (Ingestad, 1967).*

Solution 1		Solution 2			
	Amt./liter		Amt./liter		Amt./liter
Chemical	(gms or ml)	Chemical	(gms or ml)	Chemical	(gms or ml)
NH_3 (25%)	3.8	KNO_3	34.4	$MnSO_4 \cdot H_2O$	0.20
$NaNO_3$	105.0	HNO_3 (70%)	2.2	$CuSO_4 \cdot 5H_2O$	0.06
KH_2PO_4	28.6	$Mg(NO_3)_2 \cdot 6H_2O$	44.9	H_3BO_3	0.57
K_2SO_4	24.5	$Ca(NO_3)_2 \cdot 4H_2O$	20.7	MoO	0.0052
		Sequestrene (NaFe, 13%)	3.8	$ZnSO_4$	0.066

*Concentrates should be prepared in two separate solutions to prevent precipitation and/or floculation of chemicals.

Table 2. Amounts of EACH nutrient solution concentrate (Table 1) needed for each liter of solution to be used in "watering" plants to provide varying solution concentrations (nutrient "levels").

Concentration ppm	ml of EACH "concentrate"	Concentration ppm	ml of EACH "concentrate"
10	0.10	200	1.97
20	0.20	300	2.96
30	0.30	400	3.94
40	0.39	500	4.93
50	0.49	750	7.39
100	0.99	1000	9.86

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EFFECT OF FERTILIZER NITROGEN ON THE DEVELOPMENT OF LEGUME NODULES

BACKGROUND

Roots of legumes (peas, beans, soybeans, clover, etc.) can be infected by a bacterium known as Rhizobium. The result of the infection is the formation of a root nodule which is a small growth on the root. The bacteria, which inhabit cells in the central portion of the nodule, are capable of converting N_2 gas from the atmosphere into ammonium. This capability is very valuable to the plant because the ammonium supplied by the bacteria is sufficient to meet nearly the entire nitrogen (N) requirement of the plant so that expensive N fertilizer does not have to be applied to legumes if they are well nodulated.

For reasons that are not entirely understood, nitrogen fertilizer can inhibit the formation and growth of nodules. This is an unfortunate situation for farmers because there are times when they would like to apply fertilizer N and still have nodules actively fixing N.

PROBLEM

The purpose of this experiment is to determine how much fertilizer N is required to inhibit nodule formation and growth of nodules.

MATERIALS AND METHODS

The most difficult component to obtain will be legume inoculant. Inoculant is available from farm supply stores and some garden supply stores during the planting season but may not be available during the winter months. If inoculant left over from the previous season can be obtained, it will probably still contain enough living bacteria. If no inoculant can be obtained, soil from a garden or field where the legume of choice has been grown will probably contain enough bacteria to form nodules. Note that there are different types (species) of Rhizobium for different legumes. The type of

legume (pea, bean, soybean, clover) used will depend on the type of inoculant or soil which is available.

Obtain inoculant and/or soil, seeds, pots, and ammonium nitrate or urea fertilizer. Free-draining pots are best because they are more difficult to over-water, but jars may be used. Mix 0, 125, 250, or 500 mg N fertilizer with 1 Kg of soil. A more uniform mixture will be obtained if fertilizer pellets are crushed prior to mixing. Make up enough pots to give 3 or 4 pots for each fertilizer treatment so that average results can be calculated. Inoculant can be applied by shaking inoculant and seeds in a jar or by sprinkling a small amount of inoculant on the surface of each pot and watering it in.

After planting, the soil should be kept moist but not wet. For best results, give each pot exactly the same amount of water every 2 or 3 days. If all pots do not receive the same temperature and light conditions, re-arrange pots occasionally in an attempt to provide identical growth conditons for all plants.

After 25-30 days, gently wash soil from roots. Pull nodules from roots and count and weigh them. Calculate average number and average weight of nodules per plant and draw a graph to illustrate the effect of fertilizer N on nodule formation and growth.

Possible variations: (1) Use higher or lower amounts of fertilizer than those suggested above. (2) Determine the effect of fertilizer at different growth stages, e.g., 20, 30, 40, and 50 days. (3) Try different legumes. Are all legumes equally sensitive to fertilizer N?

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4. Write to author at address below if information is not found in textbooks.

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EFFECT OF NITROGEN FERTILIZER ON THE GROWTH OF YOUNG PEAR SEEDLINGS

BACKGROUND

In pear breeding programs, seeds, resulting from controlled pollinations, are usually germinated and grown in a greenhouse

for several months before being planted in a field. Once in the field, seedings usually do not produce flowers or bear fruit for 6 or more years. This is unfortunate because the breeder would like to be able to evaluate a seedling's fruit characterisitics as soon as possible.

Research has shown that a pear seedling will not fruit until it reaches a certain height or size. Therefore, it is important to optimize seedling growth. Perhaps, while seedlings are growing in the greenhouse, optimal fertilization, supplemental lighting, and enrichment of the greenhouse atmosphere with carbon dioxide may offer a means of speeding up growth and shortening time to fruition.

PROBLEM

Determine the effect of supplemental N fertilizer on the growth of young pear seedlings. Nitrogen is usually the element essential for plant growth that is most deficient in soil. N is an essential element in amino acids, the building blocks of proteins.

MATERIALS AND METHODS

Obtain at least 36 pear seeds. (There can be up to 10 seeds per fruit.) Stick to 1 variety: Bartlett pears are the most common variety found in grocery stores during the summer or early fall. Bosc pears are often available in the fall and early winter. Anjou pears are the most common variety available in the winter and early spring.

Seeds obtained from fruit bought between July and December should be wrapped in a moist paper towel and placed in a polyethylene bag. Store the seeds in a refrigerator for 60 to 90 days. This period of low temperature exposure in a moistened state (i.e., stratification) will overcome the seed's internal dormancy. Seeds obtained from fruit bought between January and April have already been held in cold storage long enough to overcome their internal dormancy.

Fill 35 to 40 "3-inch" peat pots with a peat-vermiculite growing medium which is available in bags at most garden centers. Be sure to moisten the medium before filling the pots.

Make a hole approximately 1 cm deep in the center of the filled pot. Drop 1 seed in this hole, and pinch the hole shut.

At 20 degrees C, germination will occur within 7 to 10 days. Check the medium daily after planting and water lightly if it appears to be drying out.

To determine when to water once the seeds have germinated, squeeze a sample of the top half inch of growing medium between your thumb and forefinger. If water squeezes out easily, there is adequate water. If the medium feels slightly moist but water is difficult to squeeze out, it's time to water. Apply enough water to completely soak the medium to the bottom of the pot.

After the seedlings produce their first true leaves, add 0, 1/2, 1, 2, or 4 grams of ammonium nitrate fertilizer (ammonium nitrate contains 33% N) to each of 5 or 6 peat pots.

After 40 to 60 days from planting, measure the height of each plant. Then cut the plants off at the soil line, and weigh the

above-soil portion of each plant. Calculate the average height and weight for each nitrogen fertilizer treatment. Draw a graph to illustrate the effect of N fertilizer on the growth of young pear seedlings. Can you predict from this graph what the optimum amount of N fertilizer should be?

VARIATIONS

Apple seeds can be substituted for pear seeds.

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EFFECT OF PLANT GROWTH REGULATORS ON TOMATO AND CUCUMBER PLANTS

BACKGROUND

The story of plant growth regulators is one of the interesting chapters in science. Like most discoveries and developments, it came as a gradual unfolding of theories from a great number of workers over a long period of time. The growth stimulating effects of the gibberellins and the growth inhibiting effects of compounds like Alar (daminozide) have been studied extensively. A more recent compound is Ethrel (ethephon) that releases ethylene in plant tissues. Ethylene has many effects on plants including promoting root formation, fruit ripening and senescence.

Depending upon the species of plants used, it would take a complete growing cycle of 3 to 4 months to observe all the responses of plants to these growth regulators. Consequently, this experiment is designed for young seedlings. It is also possible to conduct this experiment with one or two of the chemicals on either cucumber or tomato seedlings if time and space are limited.

PROBLEM

What are the effects of plant growth stimulators and inhibitors and a senescence (aging) promoting compound on young tomato and cucumber plants? What are some possible reasons for these results?

MATERIALS AND METHODS

1) Seedling tomato and cucumber plants; 2) GA_{4-7}, Alar and Ethrel; 3) Pots (10-15 cm) plus potting soil; 4) Area for growing plants; 5) spray applicator for applying chemicals.

1. Check or control
2. GA_{4-7} - 150 ppm
3. GA_{4-7} - 300 ppm
4. Alar - 5,000 ppm
5. Alar - 10,000 ppm
6. Ethrel - 250 ppm
7. Ethrel - 500 ppm

You will have to calculate the correct amounts of the basic chemicals to make these concentrations in water for treating the plants. Spray the plants with the above solutions until the leaves are wet at the following treatment times:

1. First true leaf visible and about 2.5 cm long or wide.
2. Three leaf stage when the third true leaf is about 2.5 cm long or wide.
3. Five leaf stage when the fifth true leaf is about 2.5 cm long or wide.

Take data on foliage color, plant height, internode length, number of nodes to the first flower or flower cluster, number of flowers per cluster and the number of flowers that set fruit on the first cluster (tomato only), the sex expression of the first flower--staminate or pistillate (cucumber only); adventitious roots on the stems (tomato only).

NOTE: GA_{4-7} can be obtained from Abbott Laboratories, Chemical and Agricultural Products Division, North Chicago, IL 60064; Alar can be obtained from Uniroyal Chemical, Nagatuck, CN 06770; Ethrel is available from Union Carbide Agricultural Products Co., P.O. Box 12014, Research Triangle Park, NC 27709. Be sure to request chemicals early because it will take time to obtain them.

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EFFECTS OF SALINITY ON STRAWBERRY PLANT GROWTH IN CONTAINERS

BACKGROUND

Soils vary in the concentration of salts present in the soil water. Salts are released into the soil solution as soils weather. Salts can also be added in fertilizers, in saline irrigation water, or in water from almost all sources. Of course, the more pure the water, the less salt is added.

Species of plants vary in their growth response to soil salinity. Some species of plants can grow well in very saline soils. These plants are called halophytes. Halophytes are often found growing near the oceans or in deserts. None of our agricultural plants are halophytes.

In the midwest USA, high salt levels are not usually a problem in soils or in crop production. The rainfall and melting snowfall leach away salts from the topsoil. In other areas of the USA, salt buildup can be a stress factor limiting agricultural crop productivity. For example, in the southwest and parts of California almost all water is supplied to plants by irrigation. Over the years, salts build up in the soil from soil weathering and evaporation of water from the surface with little leaching.

Our common fruit plants, such as strawberries, are grown throughout the temperate zone. This includes rain-leached soils of the midwest and irrigated soils to the southwest and California. Are fruit plants sensitive, moderately sensitive, moderately tolerant, or tolerant of soil salinity? The more salt sensitive a plant is, the more yield decreases as salinity rises. At what level of soil salinity does salt become a limiting or stressful factor to fruit plant growth? Strawberry provides a good test system as it is fine rooted and responds quickly to changes in the environment.

PROBLEM

Study the effects of various concentrations of saline water on strawberry plant growth and determine an approximate minimum salt concentration which is harmful to growth.

MATERIALS AND METHODS

1. Twenty-five strawberry plants (may be ordered in late-winter as dormant crowns from various nursery catalogs). The cultivar is your choice.

2. Plastic pots (5-6").

3. Soil mix (combination of various of the following: soil, vermiculite, perlite, peat).

4. Slow release fertilizer, e.g. Osmocote 10-10-10, incorporated at recommended rate into soil mix prior to planting.

5. Saline solutions made by adding NaCl or KCl to warm distilled water in the following amounts: 0 mg/liter, 300 mg/liter, 600 mg/liter, 1200 mg/liter, 2400 mg/liter.

PROCEDURE

Overview: Grow strawberry plants in pots in greenhouse for 6-8 weeks, water with various salt solutions, visually or photographically record effects on plant growth once per week, and at the end of 6-8 weeks measure plant fresh weights.

1. Combine enough soil for one pot with recommended amount of Osmocote fertilizer for one pot and shake well for 30 seconds in a plastic bag. Pour "soil plus fertilizer mix" into a pot while planting the strawberry crown (may require 3 hands). Do this for each of the 25 plants. Place pots on greenhouse bench and randomly assign and label each pot as to salt solution it is to receive (5 plants per solution). Water each plant with the correct salt solution.
2. Grow the plants in a warm greenhouse for 6-8 weeks. Water each pot as necessary with the proper salt solution. Record observations on each plant's growth and development once per week.
3. To terminate the experiment, wash each plant well (tops plus roots) and record the fresh weight. Visually or photographically compare root growth among treatments.

RESULTS

Prepare a chart summarizing the effects of the salt solutions on plant growth. It should be divided into the following sections: Treatment, week number, description of visual effects on plant development and plant fresh weights.

QUESTIONS

1. Are strawberry plants sensitive to salt? Did higher concentrations alter plant growth more than lower concentrations?
2. Was there plant to plant variation in growth response? What are the factors which could be responsible?
3. Did different treatments use different amounts of saline solution? Which treatment required the most?; the least? Why?
4. Were salts added to the pots from any other source than the saline solution?
5. Were there differences in plant root growth among treatments? Do you think it is the strawberry root system or the shoot system that is first affected by salt?
6. Would you expect a different cultivar of strawberries to respond differently to these treatments? What about a different fruit plant?
7. Could strawberries growing near a highway in the midwest be affected by salt?

8. Any idea why some plants can tolerate salts and others cannot?

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GEOTROPISM

BACKGROUND

We take for granted the fact that the photosynthetic portion (shoot) of a plant grows upward while the water and mineral absorbing portion (root) grows downward. However, this is not a matter of chance but instead is a response of the plant to gravity. (Note that seedlings growing in the space shuttle would grow in random directions because of the lack of gravity.) This response of plants to gravity is known as geotropism.

The geotropic response is known to be due to the spatical distribution of hormones within a plant tissue. While the chemistry underlying the response is not completely understood, it is realtively easy to conduct simple studies of the response.

PROBLEM

The purpose of this project is to investigate the geotropic response of seedlings and to determine the time required for the induction of the response.

MATERIALS AND METHODS

Seeds of any plant may be used. Corn is recommended because it is readily available, has a large, visible embryo, and can be positioned with the point of root (radicle) emergence down. Sand, vermiculite, or perlite will be convenient for growing seedlings but anything may be used. Clear glass containers (water glasses, jars, etc.), cheesecloth, and rubber bands are required.

Fill containers with growth medium and plant seeds about 1 inch deep at one edge of the container so that the embryo can be seen from the outside. Water until the medium is moist but not soaked; add water as needed to keep the rooting medium moist. Observe germination and early growth and take notes on growth rate.

When coleoptiles (embryonic shoots) have just emerged from the medium, cover containers with a piece of cheesecloth and fasten with a rubber band. Holes for the colepotiles can be made by spreading the threads of the cheesecloth with a pencil. Now rotate the containers various directions and, leaving containers in various positions for several days, observe and record the direction of growth of roots and shoots.

Conduct an experiment to determine how long seedlings must be placed in a new orientation before roots and shoots respond to gravity by altering their direction of growth. Limit the rotation treatment to horizontal (i.e. 90^0 from the original position). Suggested times are 1, 2, 4, and 8 hours, i.e. the containers are placed in a horizontal position for these times and then returned to the verticle. The question to be answered is whether any curvature can be detected in the root or shoot, and the response may not be visible until the day after seedlings have been returned to the verticle position. The experiment should be repeated several times, and data on the amount of curvature for each time treatment should be recorded.

Possible variations: (1) Use different times than those suggested. What is the shortest time when a change in direction can be detected? (2) Try different seeds. Do all roots and shoots respond to gravity in the same way? (3) Attempt to get a root to change directions several times. Can you make a root grow in the shape of a letter "C"? The shape of an "O"?

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4. Write to author at address below if information is not found in textbooks.

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PREDICTING THE GROWTH AND DEVELOPMENT OF KENTUCKY BLUEGRASS BASED ON GROWING DEGREE-DAYS

BACKGROUND

Kentucky bluegrass is a major cool season turfgrass species found on golf courses, home lawns and athletic fields. A healthy,

dense stand is achieved in part by nitrogen applications in the spring. A major goal of turfgrass managers is to apply the nitrogen at the time that maximum efficiency and response can be achieved. Currently, turfgrass managers apply nitrogen on a fixed calendar date. However, weather conditions change from year to year and location to location resulting in inconsistent nitrogen responses.

Three stages of Kentucky bluegrass development occur in the spring. They are: 1) spring green-up, 2) initiation of vegetative growth, and 3) seedhead production. Spring green-up is defined as that period where Kentucky bluegrass turns from a tannish color to green. Initiation of vegetative growth has been reported to begin at 10°C. A method of predicting when these stages occur based on environmental conditions would result in more efficient and timely applications of nitrogen. Golf course superintendents and lawn care professionals concerned about proper timing of nitrogen applications would benefit from this work.

Growth and development of some plants show a temperature response to a number of physiological processes. One method of measuring temperature affects on growth is correlating growing degree-days or heat accumulation units with stages of development. Growing degree-days are calculated in a number of ways, but the most common is given as follows:

$$GDD = \frac{(max + min)}{2} - BT$$

where GDD = growing degree days; max = maximum daily temperature, min = minimum daily temperature and BT = base temperature for growth (10°C).

PROBLEM

Develop a model that predicts spring green-up, initiation of vegetative growth and seedhead formation of Kentucky bluegrass based on growing degree-days.

MATERIALS AND METHODS

Record maximum and minimum daily temperatures from a turf composed of at least 50% Kentucky bluegrass. For best results a hygrothermograph should be used to record temperatures. If unavailable, contact a weather reporting station for necessary temperatures. These temperatures will be necessary to calculate growing degree-days. Measure vegetative growth from initiation to seedhead formation and determine the date spring green-up occurs. Vegetative growth should be measured prior to each mowing. Measure the height to the turf from the soil surface to the top of the canopy. Data should be expressed as an accumulated total, a rate change (growth between successive mowings) or as a percent of the accumulated total. Correlation of growing degree-days to the corresponding stage of growth should be done to develop the model.

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PREHARVEST FACTORS AFFECTING LONGEVITY OF POTTED CHRYSANTHEMUMS

BACKGROUND

The potted chrysanthemum is popular both as a florist crop and for interior display in malls, offices, and public buildings. The longevity, or keeping quality, is affected by postharvest conditions such as light levels, temperature, and watering practices in the interior environment. However, various factors during the growth of the crop (preharvest factors) may also be important for longevity. These include growing media type, media water holding capacity, fertilization regimes, time of fertilizer termination, and soil soluble salt levels.

PROBLEM

Determine the relationship between several preharvest factors and the longevity of the potted chrysanthemum. The impact of these factors upon the growth, appearance, and scheduling of the crop will need to be weighed against any possible longevity gains. The feasibility of grower implementation of the recommendations will need to be determined.

MATERIALS AND METHODS

Greenhouse space will be required for these studies. Rooted cuttings may be purchased from a commercial supplier (see references 4 and 6). Up-to-date cultural information can be obtained from these suppliers or from your county Cooperative Extension Service agent. Reference 3 contains a complete review of potted chrysanthemum cultural information. The chrysanthemum is a photoperiodic plant requiring short days to flower. Therefore, this research may require shading the plants each evening during their growth. However, the chrysanthemum will flower under natural daylength conditions during the fall of the year provided the plants are not exposed to artificial light sources at night.

Various preharvest factors may be manipulated. One possibility would be the inclusion of increasing proportions of soil into a commercial artificial soil mix for potting of the cuttings (2). Different rates of commercial fertilizer or termination of ferilization at increasing time intervals before harvest could also be investigated. Combinations of different factors could also be manipulated.

Upon flowering, plants will need to be placed in a simulated home environment for quality and longevity evaluation. This will involve establishing criteria to determine when the plant quality has deteriorated below consumer acceptability. The criteria should include observations of flower and leaf condition. Establishment of a consumer (student) panel that could evaluate the plants in their own homes could also be a possible method of quality evaluation.

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ROLE OF LIGHT IN FRUIT COLOR FORMATION

BACKGROUND

Fruit of most deciduous trees that we eat changes color as they mature from green to red, blue, purple, or yellow. These pigment changes are indications of both quality and stage of maturity. Some pigment changes require direct light on the skin of the fruit, and others do not. Red, blue, and purple colors of fruits result

from synthesis of the anthocyanin pigment. Red pigmentation is affected by various cultural practices and environmental factors such as pruning, thinning, fertilization, temperature and light.

Factors that result in a high level of carbohydrates in the fruit during the preharvest period tend to increase anthocyana pigments. Any factors such as clouds, rain, haze, fog or smoke which block incoming radiation can reduce total photosynthate production and carbohydrate levels. Some red-colored fruit such as tomato, grape and cherry do not require direct light for red color formation, while others are very specific in requiring direct light.

Of the 43% of incoming light that reaches the earth's surface, 25% is direct light and 18% is diffuse sky radiation. Both are important in the pigmentation of fruit. Ultraviolet and blue light are more effective in producing anthocyanin pigments in fruits with a light requirement than are the longer wavelengths. An early study found that ordinary window glass changed both the intensity and quality of light and reduced pigment synthesis in detached apple fruits.

PROBLEM

Investigate the role of both the quantity and quality of light in red color formation of apple. Is it necessary for direct light to the fruit for red color formation or can it be indirect? Do different levels (quantities) of light influence the amount of color formation? When in the season is light most important for color development? Is the quality of the light important?

MATERIALS AND METHODS

Beginning before any red color developes, enclose apples at various times in bags that impose varying degrees of shade. Construct the bags of old nylon stockings or other material that permits some light and compare to a bag that excludes all light and no bag at all. Another approach would be to apply and remove electrician tape to the apple surface at various times. Be certain that fruit to be compared are from similar orientations in the tree and exposure to sunlight. The influence of light quality could be compared by using as bags different colored light transmitting films. Color should be rated on the percentage of the fruit surface that is red and on the intensity of color.

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MAKING WASTES USEFUL - RESOURCE RECOVERY

BACKGROUND

We Americans produce an average of more than 6 pounds of wastes per person a day. That includes the waste from industry, from farm, from business, from homes. Some believe that the total may be nearer 20 pounds per capita in some places. We call garbage, ashes, abandoned cars, manure, refuse, cans, leaves, chemical and metal residues, for examples, wastes. It costs us great sums of money to dispose of wastes safely. Improper waste disposal can effect the quality of our environment, our air, our water, our land. We have many controversies where to put waste landfills. Finding land sites to dispose of waste is more and more difficult.

Resource recovery can lower the costs of waste disposal. It can lessen the need for landfills, lessen the problems of pollution and lessen the demand for new natural resources. Using wastes can create new jobs, new income, new businesses. And many wastes are made useful. Manure can be used for fertilizer. Aluminum cans can be recycled. Some wastes can produce energy. Waste heat can be captured and used. One of our challenges is the conversion of waste into new resources for mankind - called resource recovery.

PROBLEM

Develop a use for waste product; contrast it with other ways of disposing of it; and, determine how it might be feasible. Do not feel restricted because there may already be a use for a waste. Maybe you can find a better one.

MATERIALS AND METHODS

It is suggested that you select one waste product for your experiment. Examples include polluted water loaded with silt; a stream contaminated with mine acid; sludge from a sewage treatment plant or industry; litter; garbage; paper; cans; sawdust; manure, etc. Does algae have a use? Or its components? What can you extract from leaves? We have a staggering "crop" of them each fall. Or you might want to select the waste from one industry in your area. We suggest caution on the waste you select because of possible hazards. Seek the cooperation from your industry or municipal water plant and to get waste samples. You can set up your experiment with that waste on a small scale.

You might want to consider making a model to show the waste "chain" of a product - like tomatoes from field to cannery to home to disposal to use then of the cans, sludge and other waste.

You might try using earthworms in a controlled bin, to decompose a mixture of municipally-digested waste, grass cuttings and newspaper cuttings to produce a compost product for gardening and more earthworms for fishermen. Keep some costs and see how you make out as a researcher and businessperson. A Planet Earthworms company in Colorado is trying this on a larger, more sophisticated scale (see pg. 190 of reference 3).

You could try to show the business-side of resource recovery. Collect the waste paper from an office or your school; see how much accumulates in a day, or a week, and add that for a year. Then get some prices from waste paper dealers to see the value of this paper. You could do the same on the newspapers collected and saved from your own home. How many dollars does it amount to?

You might want to make a map or exhibit of your state to show where recycling of waste is done, and what kinds of wastes are being used. You could use photographs, or drawings, or advertisements to illustrate. (Try the Ohio Environmental Protection Agency, OEPA, 361 East Broad Street, Columbus, Ohio 43216; 614-466-8565 or a local OEPA office for information.)

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5. Contacts with your county Cooperative Extension Service agent, soil conservationist, environmental protection office, municipal water or sewer plant, industry manager or plant chemist.

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SEED GERMINATION AND VIGOR TESTING

BACKGROUND

Probably the single most convincing and accepted index of seed quality is the ability to germinate. Germination is defined as "the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions" (2). Germination tests are conducted under conditions which are known to promote germination such as optimum temperature and moisture conditions.

Although seed germination is determined under favorable conditions, these conditions are seldom encountered in the field under the cold, wet soils of spring. Consequently, a new generation of seed quality tests called vigor tests has evolved. Seed vigor is defined as "those seed properties which determine the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions" (1). Seed vigor tests often employ some form of stress on seeds to separate strong and weak seeds from seeds which would be considered germinable under the same standards established for the germination test. One of the most accepted seed vigor tests is the cold test which places seeds in soil at cold temperatures prior to exposing them to optimum germination conditions. This test functions by simulating the cold, wet soils which are found in early spring plantings.

PROBLEM

Conduct and compare the results of a standard germination test and a cold test.

MATERIALS AND METHODS

Paper towels, plastic bags, saran wrap, two lots of soybean and/or corn seeds, cafeteria trays, refrigerator and soil (preferably from a soybean and/or corn field)are required for this study.

To conduct the standard germination test, place two layers of moistened paper towels on the table and add 25 evenly spaced soybean or corn seeds from the two seed lots on the toweling. Cover the seeds with another two layers of moistened paper towels, fold the towels one inch from the bottom and then roll the paper towels

and enclosed seeds into a tube. This tube is called a "rag doll" by seed technologists. Repeat this procedure three more times so that you have four "rag dolls" containing a total of 100 seeds. Place two rubber bands, one at the top and one at the bottom, of the "rag dolls" and cover them with a small plastic bag to minimize moisture loss from the paper towels. Place the covered "rag dolls" upright in the room at room temperature insuring that there is no moisture loss. If this occurs, rewater as necessary. After seven days, open the "rag dolls" and count the number of germinated seedlings which possess both a root and a shoot.

To conduct the cold test, obtain a cafeteria tray and place four layers of moistened paper towels on the bottom of the tray. Add 100 soybean or corn seeds to the paper towels and then carefully cover the seeds with a layer of dry soil which is even with the top of the cafeteria tray. Add enough water to the soil to make it "sticky." If possible, cover the tray with saran wrap or a plastic bag to keep the moistened soil from drying out. The tray, soil and seeds are then placed in a refrigerator for seven days. After this period, they are removed from the refrigerator and allowed to germinate at room temperature for four days. Count the number of seedlings which have emerged from the soil and compare these results against the germination test values for the same seed lots.

Answer the following questions: Why were the cold test results lower than those recorded for the germination test? If you had to select a seed lot for planting based on these two test results, which test result would you select and why?

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THE DECOMPOSITION OF ORGANIC MATERIALS ADDED TO SOILS

BACKGROUND

A major problem of society is the disposal of organic waste materials. Currently, much of the sewage sludge is spread on soils. Likewise, the wastes of food processing plants, paper manufacturing plants, and livestock feeding operations are spread on soils.

Other organic materials are added to soils by spills, e.g. oil spills. Through the centuries, plant residues and animal manures have been used by farmers as sources of plant nutrients. The organic materials must be decomposed before the nutrients are available to the plants. The nutrient needs of the soil organisms must be satisfied before nutrients are available to the plants. When residues are low in a nutrient, such as nitrogen, the addition of that nutrient to the residue will increase the rate of decomposition.

The rates of decomposition of organic compounds are often determined by measuring the quantities of carbon dioxide produced by the soil organisms. Carbon dioxide is one product of respiration. The chemical reactions used in this experiment are:

$$\text{Organic materials} \xrightarrow{\text{microbes}} CO_2$$

$$CO_2 + NaOH \longrightarrow NaHCO_3$$

An excess of NaOH is used and therefore the vial (see methods) will contain both $NaHCO_3$ and NaOH.

$$NaOH + NaHCO_3 + BaCl_2 \longrightarrow \underset{\text{white ppt.}}{BaCO_3} + NaCl + NaOH$$

Titration of NaOH to determine the quantity of NaOH not neutralized by CO_2.

$$\underset{\text{(in vial but do not react with HCl)}}{NaOH\ (+BaCO_3 + NaCl)} + HCl \longrightarrow NaCl + HOH$$

At end point, one mole of HCl has been added for each mole of NaOH in the flask.

PROBLEM

Compare rates of decomposition of various residues added to soils.

MATERIALS AND METHODS

Materials - 1 pint jar for each organic material; 1 flat-bottomed vial for each jar; soil, organic materials (e.g. grass clippings, leaves, pine needles, sugar, starch, straw, paper, and protein), water, 2.00 M NaOH, phenolphthalein indicator solution, 1 M $BaCl_2$, 0.50 M HCl, buret, ring stand, balance, and 125 ml Erlenmeyer flask.

1. Add 50.0 g. of soil to each pint jar (jars should be sterilized).
2. Mix 1.0 g. of organic material into the soil of each jar (e.g. ground leaves to jar A and sugar to jar B). Have one jar as a control - soil but no organic material.
3. Add sterile water to moisten the soil and organic materials until the soil is moist but not sticky or muddy.
4. Add 15.0 or 20.0 ml of NaOH to each vial, place the vial in the jar and seal the jar.

5. Let the microbes decompose the materials for three or four days. If room temperature is cool, place the jars in a warm oven (approximately 35°C).
6. Open a jar, transfer the contents of the vial to a 125 ml Erlenmeyer flask. Rinse the vial with 20 ml of $BaCl_2$ solution, and transfer to the 125 ml flask. The white precipitate is $BaCO_3$. Add several drops of phenolphthalein.
7. Titrate the contents of the 125 ml flask with the HCl solution until the pink or red color disappears.
8. Add another 15.0 or 20.0 ml of NaOH to the vial, place the vial in the jar, seal, and let the sample incubate again for 3 or 4 days. Repeat steps 6 and 7. Continue the experiment as long as desired.
9. Calculate the quantity of carbon dioxide produced and plot on graph paper - time vs CO_2 produced.
10. Write a conclusion.

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DEGRADATION OF PETROLEUM PRODUCTS IN SOIL

BACKGROUND

With increased use of petroleum products as sources of energy or for industrial purposes, increased importance has been placed on investigating their rates of breakdown in the environment. Waste disposal of petroleum products and clean-up of oil spill sites has required the soil scientist to study this problem. Crude oil is a complex mixture of carbon and hydrogen compounds which is fractionated during the refining process to yield specialized products. Refining produces, in order of increasing molecular weight, gasoline, diesel fuels, kerosene, engine oils, lubricating oils, petroleum waxes, petrolatum, and bitumens or asphalts. Because the molecular weight and chemistry of each of these fractions is different, their degradation rate in soils is also different. Degradation of the petroleum products in soil occurs as a result of microbial activity. Any treatments which will stimulate microbial

growth as a whole, or a specific segment of the microbial population that is capable of degrading the petroleum product applied, will affect the degradation rate observed.

PROBLEM

Determine the comparative rates at which various petroleum products decompose in soil. How do soil types and management factors affect the rate of degradation of the various products?

MATERIALS AND METHODS

Soils, petroleum products, soil containers (quart jars work well), small collection vessels, standard sodium hydroxide (0.02 M), standard acid (0.01 M), and phenolphthalein indicator (1 g per 100 ml of 95% ethanol) will be needed.

Mix the petroleum products with the soil or apply drop wise on the entire soil surface. Be sure to replicate treatments and to include controls (untreated) soil samples in the experiment. Suspend a small collection vessel containing the standard sodium hydroxide over the soil using a fine wire or alternatively gently place the vessel directly on the surface. Seal the soil container and allow any CO_2 that is evolved to be trapped in the sodium hydroxide. (What is the chemical reaction involved in the trapping procedure?) After 2, 4, and 7 days and at weekly intervals thereafter (until 2 to 3 months have passed) replace the small collection vessel with one containing fresh sodium hydroxide. Titrate the sodium hydroxide removed with the standard acid using phenolphthalein as an end-point indicator. (One ml of 0.01 M acid is equivalent to how many mg of carbon dioxide?) Prepare a graph of the results with time (days) on the x-axis and the cumulative amount of CO_2 evolved on the y-axis.

Suggested variables to investigate include:

1. Petroleum products and rates of application. Apply various petroleum products such as oils, diesel fuel, gasoline, etc. to the soil. Different rates of the same material may also be applied. Suggested ranges of application rates are from 50-500 mg of petroleum product applied for each 100 g soil.
2. Soil types. Compare the degradation rates in a garden soil and a sandy soil.
3. Soil treatments. Include with the organic materials a nitrogen fertilizer, a microbial poison such as sodium azide, or heat the soil in the oven at 300°F (150°C) for six hours before applying treatments.

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EARTHWORMS AS SOIL-FORMING FACTORS ON MINESOILS

BACKGROUND

The five soil-forming factors of climate, organisms, relief, parent material and time interact to form soil from rock. Among soil-forming organisms, earthworms are important because they redistribute plant litter and soil, and create macropores of various sizes. The nightcrawler, Lumbricus terrestris, because of its large size, strength, and feeding habits, moves significant quantities of plant litter from the soil surface into its burrow, thus helping to form topsoil of high organic content while creating soil pores and aggregates, primary soil particles grouped together to form a larger mass.

PROBLEM

Land areas reclaimed after surface mining for coal often lack physical and chemical properties near optimum for sustained plant growth. Soil bulk density (weight per unit volume of soil) is high due to compaction by heavy earthmoving equipment. Conversely organic matter content, macro-porosity, the proportion of soil pores greater than 5 mm in diameter, and aggregation may be low. Some questions:

1. Can Lumbricus terrestris alter minesoil porosity, bulk density, organic matter content and aggregation?
2. If samples of minesoil are packed in containers at different bulk densities, how will surface deposition of earthworm cast vary?
3. What are the food preferences of L. terrestris among plants commonly used in revegetating minesoils?

MATERIALS AND METHODS

Establish microcosms of minesoil, earthworms, and plant litter in number 10 tin cans or other container. You could obtain minesoil from a local surfacing mining operation or from the Ohio Mining and Reclamation Association. Lumbricus terrestris (night crawlers) are available from bait dealers or you can pick your own on damp nights, using a red light.

1. To study food preferences, offer the earthworms a mixture of known dry weights of different kinds of plant material. Some choices would be leaves of oak, sugar maple, tuliptree, alder, sycamore, basswood, white pine needles, grass clippings, dandelion leaves. After a period of time, separate the litter remaining on the soil surface and reweigh. You need a control without earthworms to account for decomposition by other agents.
2. To study macroporosity, after the burrow system of the earthworms is well established, flood it with a slurry of plaster of Paris and water. Then when the plaster has set, you can separate the cast of the burrow system from the soil and measure its volume. Liquid latex can be used in place of plaster if available (Ward's Scientific, Rochester, N.Y.).
3. To study cast deposition at different bulk densities, pack different amounts of minesoil in the same volume to give different weights of soil per unit volume. Establish earthworms and, after a period of time, sort out and weigh the earthworm casts that have been deposited on the surface. The casts are a mixture of soil and organic matter that has passed through the earthworm gut.

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USING SOIL TO TREAT WASTES

BACKGROUND

Soil has always been used for disposal and treatment of wastes including garbage (as in garbage dumps and landfills), manures and sewage sludges and remains of deceased animals and humans (burial). Today, more complex, and potentially more hazardous, organic chemicals are placed in soil where soil microorganisms are utilized to break them down to harmless products.

Decomposition of organic compounds in soil is primarily performed by heterotrophic bacteria and fungi. These are microorganisms which derive energy and carbon for biomass growth through the process of respiration. In respiration, the organic compound (represented by the empirical chemical formula CHO) is converted by the organism in the presence of oxygen to carbon dioxide and water, biomass and energy:

$$CHO + O_2 \longrightarrow CO_2 + H_2O + \text{biomass} + \text{energy}$$

The rate at which respiration occurs is proportional to the amount of CO_2 produced, and CO_2 concentration can be monitored to measure the progress of the reaction.

PROBLEM

Measure the effects of environmental (e.g., soil moisture content, temperature, nutrient supply, chemical environment) and substrate (type of waste material, e.g., a pesticide, sewage sludge, shredded newspaper) characteristics on the efficiency of organic waste degradation in soil as measured by CO_2 evolution.

MATERIALS AND METHODS

The soil/waste mixture is contained in a vessel such that the CO_2 produced can be collected and measured. A simple system utilizes a small (0.5-1 liter) jar with a tight screw-cap lid. The soil/waste mixture is placed in the jar to allow 50-75% head space and a small vial of 2M NaOH is placed on the soil surface to trap the CO_2. The jar is periodically opened and the excess NaOH is titrated against standard acid in the presence of 1M $BaCl_2$ to precipitate $BaSO_4$ which would otherwise interfere with the titration. A jar containing no waste is used to determine CO_2 produced from background decomposition of soil organic matter. The jars should be incubated for at least four weeks and CO_2 evolved should be measured each week. The cumulative CO_2 evolved is plotted against time and the rate of CO_2 produced is calculated.

Variables which could be investigated with this system include: type and concentration of the waste; soil temperature and moisture content; soil type; soil pH; level of added nutrients, particularly nitrogen; effects of inhibitory substances such as pesticides, toxic metals, etc.

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NITROGEN LOSSES FROM UREA FERTILIZER

BACKGROUND

Urea is increasingly being used as a source of fertilizer nitrogen for crop production in the United States. Urea offers several advantages over other nitrogen fertilizers in that it contains the highest percentage of nitrogen of any solid fertilizer, it has high solubility in water, it handles and stores well and it is suitable for the production of dry or liquid fertilizer blends. However, a major limitation of urea is it's rapid hydrolysis by the enzyme urease, which is widely distributed in soil, to produce carbon dioxide and ammonia. If the soil to which the urea is added is alkaline or if the urea is applied on the surface of the soils, much of the nitrogen in the urea fertilizer is lost to the atmosphere as ammonia.

One method to overcome the ammonia volatilization problem is to place the urea under the soil surface in a fertilizer band. However, too much fertilizer placed with the seed inhibits seed germination and seedling growth. Also with the advent of no-tillage crop production practices farmers want to apply fertilizer in a broadcast application, avoiding tillage, except for seed placement.

PROBLEM

What amount of nitrogen is lost from the soil as ammonia when urea fertilizer is added to the soil? How do methods of application, pH, and soil type affect the amount of ammonia lost from urea fertilizer?

MATERIALS AND METHODS

Soil, urea fertilizer, sample containers (quart jars work well), small collection vessels, 2% boric acid, 0.05 M sodium hydroxide, standard sulfuric acid (0.003 M), ethanol, and bromocresol green and methyl red indicators will be needed.

To prepare the indicator solution, which is made together with the boric acid, dissolve 2 g of boric acid in 80 ml of hot water. Add to the boric acid 20 ml of mixed indicator prepared by dissolving 0.033 g of bromocresol green and 0.017 g of methyl red in 50 ml of ethanol. After mixing, add enough 0.05 M sodium hydroxide (cautiously) until a color change from pink to pale green is just detectable when 1 ml of the indicator solution is treated with 1 ml of water.

The urea fertilizer is added to the soil at a rate of 25 mg of urea nitrogen per 100 g of the soil. (How many pounds of nitrogen per acre would this be equivalent to?) Be sure to replicate treatments and to include controls (untreated) soil samples in the experiment. Variables that may be investigated include:

1. pH of the soil. Alter the pH by adding various amounts of baking soda or vinegar (acetic acid) to the soil. Allow the soil to react for two weeks before determining the resulting pH and applying the urea fertilizer.
2. Soil types. Collect soils from a garden, a poorly fertilized lawn and a sandy location.
3. Method of application. Apply the fertilizer on the soil surface, at a depth of 1.25 cm (1/2 inch), at a depth of 2.54 cm (1 inch), by mixing with all the soil in the top 2.54 cm, etc.

After applying treatments, suspend a small collection vessel containing 5 ml of the boric acid-indicator solution over the soil and seal the sample container (i.e. quart jar). The small collection vessel may be suspended using a fine wire or alternatively the vessel may be placed (gently) directly on the surface of the soil. The boric acid will trap any ammonia evolved and turn the indicator in the boric acid-indicator solution green. The amount of ammonia trapped can be determined by titrating the boric acid with the standard sulfuric acid until the indicator solution returns to a slight pink color. The amount of standard acid required to change the indicator back to pink color is related to the amount of ammonia evolved from the soil. (One ml of 0.003 M sulfuric acid is equivalent to how many micrograms of ammonia-nitrogen?). Place a new collection vessel over the soil daily for at least 7 to 10 days. Make a graph with time (days) on the x-axis and the cumulative amount of ammonia-nitrogen evolved on the y-axis. How do soil pH, soil types, and methods of application affect the amount of ammonia evolved?

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SOIL HEAT TRANSFER

BACKGROUND

The properties of porous media, such as soils, are of considerable scientific and practical interest at present. In particular, understanding the movement of heat and moisture in soils of different types requires careful investigation that can be undertaken at a wide variety of levels. This understanding can then be applied to various agricultural and engineering considerations. For instance, waste heat (i.e. warm water, at 80 to 110°F, rejected by some industrial or electrical generation plants) can be circulated in plastic pipes buried in the moist soil of a greenhouse. The movement of this heat through the soil both warms the soil itself and thus helps improve plant growth, and also transfers heat to the air in the greenhouse.

A second agricultural use of soil heat transfer is for "tempering" the air used in livestock building ventilation. In this use, ventilation air is drawn into a building through long drainage pipes buried about six feet deep in a field. At this depth, soil remains at a fairly constant temperature throughout the year. Thus, cold winter air can be warmed before it enters the building, and hot summer air can be cooled by the same process.

PROBLEM

Determine either the relative or the absolute heat transfer characteristics of different types of soil (sand, clay, silt loam, and mixtures of these) at different levels of moisture content.

Other investigations in this basic area could consider variations of plant growth with soil temperature or the effect of heat transfer on the temperature of the air above the soil. In addition, advanced students might want to work on a theoretical understanding of the differences observed in the primary experiments.

MATERIALS AND METHODS

The basic experimental studies can be carried out quite simply. For instance, heat transfer could be measured by observing the temperature change of a pot of water set on a pan of soil that had a heat source (Bunsen burner, hot plate - but the soil should not be heated above about 110°F) under it. Such an apparatus would

need to be thoroughly insulated around the sides to assure that the rate at which the water warmed up would be a relative measure of the ability of the soil sample to conduct heat. Soil moisture content could be measured by weighing samples before and after drying in an ordinary oven.

The heat transfer of the soil could be calibrated to obtain absolute values by making comparison trials with insulation materials of known properties. Finally, additional equipment could be used to make the measurements more accurate or to allow for consideration of the further problems mentioned above.

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SOILS - THEIR DISTRIBUTION, GENESIS, AND CAPABILITIES

BACKGROUND

Soils are dynamic, naturally occurring portions of the earth's surface which support plant growth. Soil properties are the result of climatic, biotic, and topographic factors acting on geologic parent materials over time. Although the boundaries between soils are gradual and difficult to precisely locate, soils have aerial extent which can be delineated on maps or illustrated with models of landscapes. Just as properties differ from one soil to another, soils do not all have the same capabilities for agricultural, industrial, or residential uses. Soil potentials and limitations must

be recognized in order to ensure proper use of our soils. Although soils should be used to their maximum capability, our soil resource must be conserved for future generations.

PROBLEM

Determine genetic pathways of soil formation based on soil properties and/or make land use decisions based on soil limitations and capabilities.

MATERIALS AND METHODS

Develop a project by selections from the following:

1. Describe the morphological properties of soils found at various sites in a selected landscape. Properties such as color, texture, structure, and consistence should be determined for each recognizable horizon in each soil examined. The various horizons should be identified with the proper designation. The similarities and differences observed in morphological properties among the soils can be discussed. The morphology of selected soils can be illustrated by the preparation of a monolith (a vertical column of soil mounted in such a manner to illustrate changes in soil morphology with depth), by pictures, or by construction of schematic drawings.
2. The soils described in (1) can be classified by the use of "Soil Taxonomy - A Basic System of Soil Classification for Making and Interpreting Soil Surveys." Comparison of your descriptions to the series descriptions given in the county soil survey report may enable classification at the series level so that the proper series name can be assigned to each soil.
3. Delineate the area in the landscape occupied by each soil described and classified in (1) and (2), respectively. Distribution of the soils in the landscape can be illustrated with a map, a schematic landscape drawing, pictures, or a constructed landscape model. Boundaries between soils in the landscape can be located by (a) observing changes in soil properties along transects from one soil to the adjoining soil, (b) correlating changes in soils with vegetation changes or landscape components, and (c) reference to the proper map in the county soil survey report.
4. The soil forming factors (parent material, climate, vegetation, topography, and age) which cause the soils studied to be different could be identified and discussed.
5. The potential or limitations of soils for various uses such as cropland, homes, on-site sewage disposal, landfills, and roads can be evaluated by reference to the proper tables in the county soil survey report.
6. An idealized land use plan can be developed for the landscape studied based on soil potentials or limitations. The land use plan could be illustrated with maps or models.

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NO-TILLAGE ESTABLISHMENT OF PLANTS

BACKGROUND

For centuries, man has tilled the soil to prepare it for planting. In modern agriculture, this is done by plowing to turn the top soil layer over and cover the surface trash. It also provides a good seedbed for planting. Home gardeners prepare the soil and make a seedbed by spading or with a small rototiller. This tilling of the soil (also called tillage), however, exposes the soil to erosion by wind and water.

In nature, seed produced by plants falls to the ground and some eventually grows. It may germinate on the soil surface and root into the soil. Winter conditions of freezing and thawing may help to cover the seed. Some of the seed may fall onto the surface vegetation and may or may not reach the soil where it can germinate and grow. In nature, plants produce a large amount of seed and much of it never grows. Insects, birds, and rodents eat much of the seed. The overproduction of seed assures that a few will grow to produce new plants.

In recent years, farmers have tried planting directly into untilled soil. By placing the seed in unplowed soil or sod with special seeding equipment, the farmer is attempting to assure that the seed has a better chance to germinate and grow, yet have the advantage of not disturbing the soil. This practice is called no-tillage or conservation tillage. This system of planting requires some method to control the old vegetation, usually by the use of herbicides. This is necessary because new seedlings have difficulty competing with old plants that are present. Some herbicides merely "burn off" the old plants; others actually kill them.

Terminology: Preparing a seedbed for planting as is done in gardening or in farming is called tilling or tillage. Planting without preparing a seedbed is called no-tillage or conservation tillage.

PROBLEM

1. Determine if plants can be grown successfully without tilling the soil.
2. Compare tillage and no-tillage of the soil as methods for growing plants.
3. Compare the emergence and growth of seed of several sizes planted in tilled and in untilled soil.

MATERIALS AND METHODS

1. Soil preparation
   a. Tilled soil - loose soil from a field or garden
   b. Untilled soil - lawn sod left to grow
   c. Untilled soil - lawn sod sprayed with an herbicide to kill the grass
2. Seed size
   a. Large seed such as corn and garden beans
   b. Small seeds such as radish, alfalfa, and clover

Materials:

1. Greenhouse flats or containers for soil.
2. Good garden or field soil.
3. Lawn sod with growth several inches in height.
4. Several kinds of seed of various sizes such as corn, wheat, soybeans, radishes, garden beans, etc.
5. The herbicide "Roundup" (trade-name, chemical name "glyphosate") sold as the Ortho product, "Kleenup," or Hi-Yield Brand, "Weed and Grass Killer," in ready-to-apply spray bottles in garden and hardware stores.

Methods:

1. Prepare one or two containers each of soil, of lawn sod to be sprayed with "Roundup," and of lawn sod not to be sprayed. Suggest two containers of each to duplicate each treatment (replication).
2. Spray the lawn sod of the one set with the "Roundup." Read and follow directions on the "Roundup" spray bottle. It will take a week to 10 days for the effect of the herbicide to be seen. Note: "Roundup" is inactivated by contact with the soil and is a relatively safe herbicide. However, always be careful when using any chemical, whether it is a herbicide, paint thinner, or household cleaner.
3. After about 10 days, when the treated sod is turning yellow, prepare all of the soil containers for planting. Clip the unsprayed sod very close with garden shears or scissors.
4. Plant all flats with each kind of seed. Plant in rows across each container, and label each row and each kind of seed with a small stake. Count out a specific number of seeds of each kind (i.e., 25) so that you can determine how many seeds actually emerged. Plant by making small

holes with a pencil or other pointed object. Plant corn and smaller seeds more shallow and closer together. You will want to be able to see each plant as it emerges so as to count it.

Data:

1. Record the date plants were seeded.
2. Watch for emergence from the soil and sod, and record daily the plants of each kind as they emerge.
3. After several weeks, record the height of each kind of plant in each of the three planting treatments.
4. Summarize the data as follows:
   a) Date of first emergence of each kind of plant in each of planting treatments.
   b) Rate of emergence as measured by the number of plants and each kind that emerged each day.
   c) Calculate the percent emergence as a percent of total number of seeds planted.
   d) Measure the average plant height after a period of 2-4 weeks in each kind of plant in each planting treatment.
   e) Data table: see below.
5. Are there other data that you can think of that would be of interest?

Tables:

	Soil	Killed Sod	Untreated Sod
1. Corn			
a. date of 1st emergence	___	_____	_____
b. rate of emergence	___	_____	_____
no. of plants	___	_____	_____
1st day	___	_____	_____
2nd day	___	_____	_____
etc.	___	_____	_____
total	___	_____	_____
c. percent of emergence as a percent of seed planted	___	_____	_____

2. Other species of plants as above.
3. Suggest that you develop charts, graphs, etc. to illustrate the data.

Discussions and Conclusions:

Discuss the relative success of development of each kind of plant in each soil treatment.

Note any differences between kinds of seed, i.e., effect of seed size and soil treatments.

REFERENCES

1. Triplett, G. B., Jr., and D. M. Van Doren, Jr. "Agriculture without tillage." Scientific American 236, no. 1, (1977): 28-31. Excellent reference.

2. County Cooperative Extension Service. Ask for information on no-tillage production of corn, sorghum, wheat, and forages.

3. USDA Soil and Water Conservation District. Ask for information on conservation tillage.

SUBMITTED BY Dr. R. W. VanKeuren, Department of Agronomy, The Ohio State University/OARDC, Wooster, OH 44691.

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PASSIVE SOLAR HEATING FOR RESIDENTS

PROBLEM

1. Establish the time at which the sun rises and sets and the angle made with the east-west line on the longest and shortest days of the year at the latitude of the experimenter.

2. Compare the effect of different window sizes (aperture opening) and orientation on incoming solar radiation for passive solar heating.

3. Observe the effect of overhangs on such windows.

Any of these could be done alone.

MATERIALS AND METHODS

You will have to construct a device for modeling the movement of the sun above the surface of the earth throughout the four seasons. A computer model could be written to calculate the angles and times you show them graphically. If you are adept with the computer and you wish to try doing the problem this way, Chapter 2 of Dr. Krieth's book (reference 1) explains how to calculate the movement of the sun through trigonometric methods. When you have calculated the position of the sun, however, you will have to demonstrate how that affects the amount of radiation passing through a window which is facing a certain direction. You can decide which direction the window faces and should study more than one direction.

Alternatively you can build a physical model to show the movement of the sun by making a heliodon. A heliodon is a mechanical device which illustrates the sun's apparent motion. (It is not listed in all dictionaries). There are various plans for a heliodon, but one which I have built and used successfully is detailed in Popular Science (reference 2).

Method: The first thing to do is to build the heliodon and understand how it works. The second thing is to build models of buildings, walls, gardens, etc. to place on your heliodon to study lighting, shadows, and orientation.

Use a pin or spike placed vertically in the center of the heliodon ground plane to study shadows. When you have established the times of sunrise and sunset for the longest and shortest days of the year, the angles to the north and south of the east/west line can be marked on the ground plane of the heliodon for those days.

Models of walls containing windows of various proportions can be made from a sheet of balsa wood, and overhangs can be constructed and glued to the walls. Accuracy in making the models will aid in the study. Make the models to a scale of about 1:24, or 1 inch = 2 feet. If you are modeling a single door or window, of course the model can be a larger scale than if you are modeling a house or a house and its yard with trees. Measure some of the windows and patio doors on your house to have an idea of dimensions.

Each wall can be placed on the heliodon ground plane at different orientations to study the effect of the movement of the sun on the radiation penetration into the building during the different seasons and particularly on the two days mentioned above.

After noting the movement of the sun's rays across the interior of the house, do the same observations with different overhang sizes above the windows at the top of the wall.

Note the effect of overhang size on the amount of radiation passing through the window opening by observing the size of the sunlit rectangle on the floor of the room.

REFERENCES

1. Kreith, Frank and Jan Kreider. Principles of Solar Engineering. Washington, D.C.: Hemisphere Publishing Corporation, 1978 : 37-83.

2. Allen, Edward. "Solar siter charts the sunlight." Popular Science 1978 : 152-156.

3. Duffie, J. A. and W. A. Beckman. Solar Energy Thermal Processes. New York: John Wiley and Sons, 1974.

4. Many issues of Solar Age magazines and architectural and building journals with articles on "Daylighting."

SUBMITTED BY Dr. Peter Fynn, Department of Agricultural Engineering, The Ohio State University/OARDC, Wooster, OH 44691.

TIPS FOR OBTAINING REFERENCE MATERIALS

After each project in this workbook, the author has listed references which give background information about that topic.

What if specific books or magazine articles on the list are wanted?

How do you find these or other related materials?

What if these references are not available locally?

START AT THE LOCAL LIBRARY

The first place to visit is either the school library or local public library. At the library, first check the card catalog, which can be on 3" x 5" cards in drawers or be an electronic catalog on a computer. If you want a specific book, look for it by the author's last name, or the title of the book. If you want additional or related books, look under the subject of the topic of the project. If you look for a subject and nothing is found, think of another name for that topic, or another subject which might be similar, or another, larger area under which it could be categorized.

The card catalog is like a map which tells where to go to find what you want. A number (the call number) is given in the upper left-hand corner of the card or on the left-hand side of the computer screen. That number tells the shelf on which the book will be found in the library.

Once books have been found on a topic, go to that area in the library and look for a specific book or just browse through the others on the shelves in that section. Look at the Table of Contents (chapter headings listed in order as they appear in the book) and the Index (subjects included in the book which are listed in alphabetical order). Skim the Introduction to see if the material might be useful. Also, check the copyright date of the book which is given on the back of the title page because that will tell you when the book was published and the date of the material. You should use the most up-to-date sources possible.

Articles from periodicals are given after many projects. A periodical is just another word for magazine or journal. If you want a specific article in a periodical listed, you should tell the librarian the title of the magazine and article, the date of the magazine, and the page number on which the article is found.

If you want additional magazine articles on a subject, you can use periodical indexes which are guides that tell what magazines have articles on certain subjects. These will also be found in the magazine sections in most libraries. One of the most common periodical indexes is The Readers Guide to Periodical Literature. Another index to check for comprehensive, detailed magazine articles is The Applied Science and Technology Index.

When a periodical index is used, first look up the subject. (They are arranged in alphabetical order.) Skim the titles of the articles listed under that subject and find those that might be of help to you. Write down all the information given -- the title of the article, the title of the magazine, the date of the magazine, and the page upon which the article is found, and take it to a librarian.

Libraries often have magazine articles on microfilm as well as the actual articles. A microfilm is a print of the article that has been reduced so it is too small to be read with the naked eye. The librarian will give you instructions on how to use a microfilm reader which will magnify the print.

The vertical file of pamphlets, newspaper articles, and other publications might be useful. A librarian will explain where the vertical file or pamphlet file is kept in the library. These materials are filed in large folders alphabetically by the subject. Just browsing through some of the folders, such as EXPERIMENTS or SCIENCE EXPERIMENTS, might give you ideas for posters, designs, or displays to help with your project.

Another place to check in the library is the reference section where books which cannot be checked out are shelved. These may be listed in the card catalog also. Since these references cannot be taken home, you will have to use them in the library; however, many libraries have copy machines if just a page or article is needed. Among reference books which have information on scientific topics are:

Encyclopedia of Science and Technology
Chambers Dictionary of Science and Technology
Encyclopedia of Chemistry
Realm of Science Encyclopedia
Dictionary of Biology.

A reference book which contains many additional places to look for information is The Science Fair Project Index, by Akron-Summit County Public Library System, Scarecrow Press, Inc., Metuchen, New Jersey, 1983.

Large public libraries are usually Government Depository Libraries which means they have booklets on many subjects which have been published by the U.S. Government. The librarian will be able to show you how to find these publications.

If the local library does not have the specific material nor enough additional resources on your topic, what next?

USE THE INTER-LIBRARY LOAN PROCEDURE

An important library service that you can use is called an inter-library loan. This means that the local library can borrow the book or magazine from another library. Libraries who belong to this system of borrowing from each other are members of OCLC (Ohio

College Library Centers). Even though OCLC started in Ohio, it now promotes sharing among libraries throughout all states and will furnish information whenever possible. Ask at the local library -- if it is not an OCLC member, the librarian will have information about where the nearest library is that belongs to OCLC (it may be the largest public library in your county). The libraries that belong to OCLC include the state colleges and universities and The State Libraries of each state.

A librarian will know the step-by-step process of how to apply for an inter-library loan through OCLC; however, if you want a specific book or magazine, be prepared by knowing the exact title of the book or magazine, the author's last name, publication date, and the publishing company of the book.

Inter-library loans can also be used if a person is just looking in general for materials on a subject. These materials will not be specific resources listed at the end of the projects, but they will be related to the same topic. When you request materials on a subject but not a specific book or magazine, this is called a "search."

Usually, the materials borrowed through inter-library loan will be available within two weeks after they have been requested. There is no charge unless an article has to be copied.

Another source from which to receive magazine or journal articles is the National Agriculture Library, Bettsville, Maryland 20705. Any large public library can ask for an inter-library loan from this national library, there is a charge of $3.00 for ten pages, and the loan period is one month. National Agriculture Library loans do not go through OCLC inter-library loans. There will be a separate form to be filled out by the librarian and you.

Now, suppose you have used the local libraries to find materials and/or to ask for inter-library loan. What if you still want more help?

INVESTIGATE OTHER PEOPLE AND PLACES FOR MATERIALS

The author of the project can be contacted directly by mail. Elsewhere in this Workbook are examples (good and bad) of letters to write to an author to receive more information.

Your high school science teacher and other people in the community will have science books and magazines in private collections or personal libraries. Materials and informed persons can also be found at local businesses, such as greenhouses, zoos, veterinary clinics, and environmental organizations.

Another source would be the colleges and universities in the area. The science, biology, and botany departments especially have much information on scientific topics. A telephone call or letter beforehand will save time and make your visit more productive. If you find materials there but cannot check them out, copies of pages or articles can often be made on a copy machine for a small fee.

It was mentioned before that Government Publications could be found in many large public libraries. In addition, there are 24 U.S. Government Documents Bookstores throughout the nation. They keep many of the publications on hand and will order those articles which they do not have. The price of the publications range from no charge to over $10.00. If a Bookstore orders a publication there is no shipping charge and it will take approximately three weeks to receive it. To see if a Documents Bookstore is near you, look in the blue pages in the telephone book under U.S. Government, Government Printing Office Bookstore.

ONE LAST IMPORTANT REMINDER

You should not go to one place and expect everything to be there and to be found quickly and effortlessly. To find materials (either specific books or magazines or general information on a topic) may require stops at different libraries. It may take extra time, particularly if a resource is to be borrowed from a distant library. Plan ahead and allow plenty of time to gather information.

A NOTE ON CREDITING SOURCES

When the display is made or written comments included with the work for a science fair or a class project, be sure to give credit where credit is due. If an author has been quoted directly, the words should have quotation marks at the beginning and the end of the quote and the author and title of the source given. If ideas from others have been used but not quoted directly, those sources should be mentioned when a list (called a bibliography) is made of all the places information was found.

Good luck on your project!

SUBMITTED BY Bonnie Darrow, Librarian, Upper Arlington School District, 1780 Barrington Road, Columbus, Ohio 43221.

UNACCEPTABLE LETTER*

Dr. L. B. Jones
Professor
Department of Food Science and Nutrition
ABC State University
Anytown, Ohio 43210

Dear Dr. Jones:

I am doing a science project on molds on breads. I don't know anything about this subject, so will you please send me everything you have on the subject.

I need to finish my project by Friday, so would you please hurry?

Sincerely,

Bill Smith

P.S. My friend Sally is doing her project on guppies. She asked me to ask you for information on guppies too.

- - -

This is a weak letter for the following reasons:

1. No date.
2. No inside address for return information.
3. Request is too general; asks for everying under the sun.
4. Student has not narrowed the topic.
5. Student has not exhausted local library sources first.
6. Response time (by Friday) is too short.
7. The student should not ask questions for someone else, especially when they are unrelated (guppies?).

*This letter (modified) printed with permission from Ohio Science Workbook: Energy, published by The Ohio Academy of Science, Columbus, Ohio. 1985. page 60.

ACCEPTABLE LETTER*

William Smith
123 Smith Street
Smithton, Ohio 12345
419/333-444

October 1, 1985

Dr. L. B. Jones
Professor
Department of Food Science and Nutrition
ABC State University
Anytown, Ohio 43210

Dear Dr. Jones:

I am doing a research project on the control of molds in breads. I have exhausted the resources at my school library, the local public library and the nearby college library.

A food technologist at a local commercial bakery suggested that you might be able to help me locate recent test data on the use of legal concentrations of calcium propionate, sodium benzoate and potassium sorbate as preservatives in breads. I am specifically interested in how well these preservatives inhibit mold at different levels of humidity and temperature over different periods of time. Do you have any recent reports or data which you could share with me? Would you be willing to talk with me about this request?

To help you respond to my questions, I have enclosed my research plan and a summary of the information I have collected.

Thank you for your consideration of my request.

Sincerely,

William Smith

Enclosure

- - -

This letter is more acceptable for the following reasons:

1. Includes return address, telephone number and date.
2. Student shows evidence of using local library resources.
3. Request is more specific than other letter.
4. Student is sending a description of the project and a summary of his background information. The person responding will not duplicate information already collected.

5. Student suggests that talking with someone may be helpful.
6. Student is polite ("Thank you for your...) and is not demanding that a response by sent by Friday!
7. Student doesn't ask help for his friend.

*This letter (modified) printed with permission from Ohio Science Workbook: Energy, published the Ohio Academy of Science, Columbus, Ohio. 1985. page 61.

CARE AND USE OF LABORATORY ANIMALS

The purpose of this section of the workbook is to alert teachers and students to the evolving policies on the humane care and use of laboratory animals. The principles printed below are general. The investigator using laboratory animals in a research project should consult the Guide mentioned in reference 3 below for more specific guidelines. After the experiment has been designed, and before the research methodology begins, it should be reviewed by a doctor of veterinary medicine who is certified (American College of Laboratory Animal Medicine) or has training or experience in laboratory animal science and medicine.

Principles for the Utilization and Care of Vertebrate Animals Used in Testing, Research and Teaching (3,p.82-83)

I The transportation, care, and use of animals should be in accordance with the Animal Welfare Act (7 U.S.C. 2131 et seq.) and other applicable Federal laws, guidelines and policies.

II Procedures involving animals should be designed and performed with due consideration of their relevance to human or animal health, the advancement of knowledge, or the good of society.

III The animals selected for a procedure should be of an appropriate species and quality and the minimum number required to obtain valid results. Methods such as mathematical models, computer simulation, and in vitro biological systems should be considered.

IV Proper use of animals, including the avoidance or minimization of discomfort, distress, and pain when consistent with sound scientific practices, is imperative. Unless the contrary is established, investigators should consider that procedures that cause pain or distress in human beings may cause pain or distress in other animals.

V Procedures with animals that may cause more than momentary or slight pain or distress should be performed with appropriate sedation, analgesia, or anesthesia. Surgical or other painful procedures should not be performed on unanesthetized animals paralyzed by chemical agents.

VI Animals that would otherwise suffer severe or chronic pain or distress that cannot be relieved should be painlessly killed at the end of the procedure or, if appropriate, during the procedure.

VII The living conditions of animals should be appropriate for their species and contribute to their health and comfort.

Normally, the housing, feeding, and care of all animals used for biomedical purposes must be directed by a veterinarian or other scientist trained and experienced in the proper care, handling, and use of the species being maintained or studied. In any case, veterinary care should be provided as indicated.

VIII Investigators and other personnel shall be appropriately qualified and experienced for conducting procedures on living animals. Adequate arrangements shall be made for their in-service training, including the proper and humane care and use of laboratory animals.

IX Where exceptions are required in relation to the provisions of these Principles, the decisions should not rest with the investigators directly concerned but should be made, with due regard to Principle II, by an appropriate review group such as an institutional animal research committee. Such exceptions should not be made solely for the purposes of teaching or demonstration.

REFERENCES

1. The American Association for Laboratory Animal Science will provide educational materials on the care and use of laboratory animals. There are over thirty-four local branches throughout the nation. Contact: AALAS, Suite 205, 210 N. Hammes Avenue, Joliet, IL. 60435

2. Animal Welfare Act (P.L. 89-544 as amended by P.L. 91-579 and P.L. 94-279). Available from Deputy Administrator USDA, APHIS-VS Federal Building, 6505 Belcrest Road, Hyattsville, MD. 20782.

3. Guide for the Care and Use of Laboratory Animals. NIH Publication No. 85-23, revised 1985. Institute of Laboratory Animal Resources, National Research Council. Available from U.S. Government Documents Bookstore.

4. The UFAW Handbook on the Care and Management of Laboratory Animals, 3rd ed. London: E. and S. Livingston Ltd. in collaboration with UFAW (The Universities Federation for Animal Welfare) 1967. This is a very complete resource for most questions about any laboratory animal.